NORTH CAROLINA
STATE RECORD

1964-1966 GRADUATE CATALOG

NORTH CAROLINA STATE
of The University of North Carolina at Raleigh

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North Carolina State is a land-grant institution, founded in 1887 in the tradition of the great public state colleges and universities then being founded throughout the nation. These institutions were created under the federal Morrill Act of 1862 and were dedicated to expanding the opportunities for higher education. Once primarily "agricultural and mechanic arts" institutions, they now constitute the major public universities of the nation, teaching all areas of learning and conducting work in every area of the world. This is an aerial view of the central part of the North Carolina State campus.

CONTENTS

OFFICERS OF ADMINISTRATION

NORTH CAROLINA STATE OF THE UNIVERSITY OF NORTH CAROLINA AT RALEIGH

William Clyde Friday, B.S., LL.B., LL.D., President
Donald B. Anderson, B.A., B.Sc.Ed., M.A., Ph.D., Vice President for Academic Affairs
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THE GRADUATE SCHOOL

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THE EXECUTIVE COUNCIL

The Executive Council is made up of members of the Advisory Boards of each of the three units of the Consolidated University. The President, the Vice President, the Chancellors and the Graduate Deans are ex-officio members of the Executive Council.

THE ADMINISTRATIVE BOARD AT NORTH CAROLINA STATE OF THE UNIVERSITY OF NORTH CAROLINA AT RALEIGH

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Roy Lee Lovvorn, Ph.D., Professor of Field Crops and Director of Research in the School of Agriculture and Life Sciences—Term expires March, 1965.

Patrick H. McDonald, Ph.D., Professor of Engineering Mechanics and Head of Department—Term expires December, 1964.
Howard G. Miller, Ph.D., Professor of Psychology and Head of Department—Term expires November, 1967.
T. Ewald Maki, Ph.D., Head of Department of Forest Management—Term expires August, 1964.
George W. Poland, Ph.D., Professor of Modern Languages and Head of Department—Term expires January, 1968.
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Irwin V. Sperry, Ed.D., Professor of Home Economics

THE CALENDAR

SUMMER SESSIONS

1964

First Session

June 9	Tues. (9:00 a.m. 1:00 p.m.)	Registration and fee payment. Late registration fee of $5 payable by all registering after 1:00 p.m. June 9.
June 10	Wed.	First day of classes.
June 15	Mon.	Last day for registration. Last day to withdraw with refund less $7 registration fee and last day to drop any course with refund.
June 16	Tues.	*Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in August.*
June 18	Thurs.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in July.*
June 19	Fri.	Last day to drop courses without grades.
June 30	Tues.	*Last day for taking qualifying examinations for students expecting to receive doctorate in January, 1965.*
July 2	Thurs.	*Last day for taking final oral examinations for master's degrees not requiring theses.*
July 15	Wed.	Last day of classes.
July 16	Thurs.	Final examinations.

Second Session

July 21	Tues. (9:00 a.m.- 12:00 noon)	Registration and fee payment. Late registration fee of $5 payable by all registering after 12:00 noon July 21.
July 22	Wed.	First day of classes.
July 27	Mon.	Last day for registration. Last day to withdraw with refund less $7 registration fee and last day to drop any course with refund.
July 30	Thurs.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in August.*
July 31	Fri.	Last day to drop courses without grades.
August 13	Thurs.	*Last day for taking final oral examinations for master's degrees not requiring theses.*
August 26	Wed.	Last day of classes.
August 27	Thurs.	Final examinations.

FALL SEMESTER

1964

September 8	Tues.	General faculty meeting.
September 9	Wed.	Registration day for all new students and other students not preregistered. Late registration fee of $5 payable by all who register after Sept. 9.
September 14	Mon.	First day of classes.
September 16	Wed.	Last day to register. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in January, 1965.*
September 18	Fri.	Last day to withdraw with refund less $7 registration fee. Last day to add a course.
September 25	Fri.	Last day to drop courses without grades.
September 30	Wed.	*Last day for taking qualifying examinations for students expecting to receive doctorate in May, 1965.*
November 2	Mon.	*Meeting of the Graduate Executive Council of the University of North Carolina.*
November 7	Sat.	Mid-term reports due.
November 24	Tues.	Thanksgiving holidays begin at 6:00 p.m.
November 30	Mon.	Classes resume at 8:00 a.m.

December 16	Wed.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in January, 1965.*
December 17	Thurs.	Christmas holidays begin at 6:00 p.m.
January 4, 1965	Mon.	Classes resume at 8:00 a.m.
January 8	Fri.	*Last day for taking final oral examinations for master's degrees not requiring theses.*
January 13	Wed.	Last day of classes.
January 14	Thurs.	Reading day.
January 15-22	Fri.-Fri.	Final examinations.
January 18	Mon.	*Meeting of the Graduate Executive Council of the University of North Carolina.*

SPRING SEMESTER 1965

January 27	Wed.	Registration day. All new students and all other students not preregistered. Late registration fee of $5 payable by all who register after Jan. 27.
February 1	Mon.	Classes begin.
February 3	Wed.	*Last day to register. Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in May and July.*
February 5	Fri.	Last day to withdraw with refund less $7 registration fee. Last day to add a course.
February 12	Fri.	Last day to drop courses without grades.
February 17	Wed.	*Last day for taking qualifying examinations for students expecting to receive doctorate in August, 1965.*
March 20	Sat.	Mid-term reports due.
April 5	Mon.	*Meeting of Graduate Executive Council of the University of North Carolina.*
April 14	Wed.	Easter holidays begin at 6:00 p.m.
April 20	Tues.	Classes resume at 8:00 a.m.
April 30	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in May.*
May 14	Fri.	*Last day for taking final oral examinations for master's degrees not requiring theses.*
May 19	Wed.	Last day of classes.
May 20	Thurs.	Reading day.
May 21-28	Fri.-Fri.	Final examinations.
May 29	Sat.	Commencement.

SUMMER SESSIONS 1965

First Session

June 14	Mon. (9:00 a.m.-1:00 p.m.)	Registration and payment of fees. Late registration fee of $5 payable by all who register after 1:00 p.m. June 14.
June 15	Tues.	Classes begin.
June 18	Fri.	Last day for registration. Last day to withdraw with refund less $7 registration fee and last day to drop courses without grades.
June 21	Mon.	*Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in August.*
June 23	Wed.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in July.*
July 5	Mon.	*Last day for taking qualifying examinations for students expecting to receive doctorate in January, 1965.*
July 7	Wed.	*Last day for taking final oral examinations for master's degrees not requiring theses.*
July 20	Tues.	Last day of classes.
July 21	Wed.	Final examinations.

Second Session

July 22	Thurs. (9:00 a.m.-12:00 noon)	Registration and payment of fees. Late registration of $5 payable by all who register after 12:00 noon July 22.
July 23	Fri.	Classes begin.
July 29	Thurs.	Last day for registration. Last day to withdraw with refund less $7 registration fee and last day to drop courses without grades.
July 30	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in August.*
August 13	Fri.	*Last day for taking final oral examinations for master's degrees not requiring theses.*
August 26	Thurs.	Last day of classes.
August 27	Fri.	Final examinations.

FALL SEMESTER
1965

September 7	Tues.	General faculty meeting.
September 8	Wed.	Registration for all students who did not preregister and for all preregistered students changing courses. Late registration fee of $5 payable by all who register after September 8.
September 13	Mon.	Classes begin at 8:00 a.m.
September 15	Wed.	Last day to register. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in January, 1966.*
September 17	Fri.	Last day to withdraw with refund less $7 registration fee. Last day to add a course.
September 29	Wed.	*Last day for taking qualifying examinations for students expecting to receive doctorate in May, 1966.*
October 8	Fri.	Last day to drop courses without grades.
November 1	Mon.	*Meeting of Graduate Executive Council of the University of North Carolina.*
November 6	Sat.	Mid-term reports due.
November 15-December 1	Mon.-Wed.	Preregistration. All students continuing in the spring semester must see advisors.
November 23	Tues.	Thanksgiving holidays begin at 6:00 p.m.
November 29	Mon.	Classes resume at 8:00 a.m.
December 17	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in January, 1966.*
December 18	Sat.	Christmas holidays begin at 1:00 p.m.
January 3, 1966	Mon.	Classes resume at 8:00 a.m.
January 7	Fri.	*Last day for taking final oral examinations for master's degrees not requiring theses.*
January 12	Wed.	Last day of classes.
January 13	Thurs.	Reading day.
January 14-21	Mon.-Fri.	Final examinations.
January 17	Mon.	*Meeting of the Graduate Executive Council of the University of North Carolina.*

SPRING SEMESTER
1966

January 26	Wed.	Registration for all students who did not preregister and for all preregistered students changing courses. Late registration fee of $5 payable by all who register after January 26.
January 31	Mon.	Classes begin at 8:00 a.m.

February 2	Wed.	Last day to register. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in May and July.*
February 4	Fri.	Last day to withdraw with refund less $7 registration fee. Last day to add a course.
February 16	Wed.	*Last day for taking qualifying examinations for students expecting to receive doctorate in August, 1966.*
February 25	Fri.	Last day to drop courses without grades.
March 19	Sat.	Mid-term reports due.
March 28-April 15	Mon.-Fri.	Preregistration. All students continuing in the fall must see advisors.
April 4	Mon.	*Meeting of Graduate Executive Council of the University of North Carolina.*
April 6	Wed.	Easter holidays begin at 6:00 p.m.
April 12	Tues.	Classes resume at 8:00 a.m.
April 29	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in May.*
May 13	Fri.	*Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
May 18	Wed.	Last day of classes.
May 19	Thurs.	Reading day.
May 20-27	Fri.-Fri.	Final examinations.
May 28	Sat.	Commencement.

SUMMER SESSIONS

1966

June 7	Tues. (9:00 a.m.-1:00 p.m.)	Registration and payment of fees. Late registration fee of $5 payable by all who register after 1:00 p.m., June 7.
June 8	Wed.	Classes begin.
June 13	Mon.	Last day for registration. Last day to withdraw with refund less $7 registration fee and last day to drop courses without grades.
June 14	Tues.	*Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in August.*
June 17	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in July.*
June 28	Tues.	*Last day for taking qualifying examinations for students expecting to receive doctorate in January, 1966.*
July 1	Fri.	*Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
July 4	Mon.	Holiday.
July 14	Thurs.	Last day of classes.
July 15	Fri.	Final examinations.

Second Session

July 19	Tues. (9:00 a.m.-12:00 noon)	Registration and payment of fees. Late registration fee of $5 payable by all who register after 12:00 noon July 19.
July 20	Wed.	Classes begin.
July 25	Mon.	Last day to register. Last day to withdraw with refund less $7 registration fee and last day to withdraw without grades.
July 28	Thurs.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in August.*
August 11	Thurs.	*Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
August 24	Wed.	Last day of classes.
August 25	Thurs.	Final examinations.

NORTH CAROLINA STATE TODAY

North Carolina State of the University of North Carolina at Raleigh entered the field of higher education in America in the late 1800's, the product of public demand for expansion of opportunity in higher education and for college curricula of modern character—chiefly in "the agricultural sciences and the mechanic arts."

As North Carolina's land-grant university, "State" was founded under terms of the Federal Morrill Act of 1862, which provided for the establishment of at least one public college of this type in each state and territory. These institutions, sharing a common educational philosophy and nature, became known as "land-grant colleges" since public lands were used for their founding.

North Carolina State opened in 1889 with 45 students. Enrollment now totals slightly more than 8,000, with over 1,200 students engaged in graduate study.

"State's" name has been changed three times in its history, in each instance the result of the expansion of the college's programs or in connection with major legislation providing for the orderly development of higher education in North Carolina. The most recent change came in 1963 when North Carolina reaffirmed its intent to maintain the concept of one Consolidated State University composed of several campuses, and with exclusive jurisdiction to grant Ph.D. degrees and having primary responsibility for research.

"State," as with its sister land-grant institutions, began as a state college of agriculture and mechanic arts and bore that name. It became North Carolina State College of Agriculture and Engineering in 1917. In 1931 "of the University of North Carolina" was added when the concept of the Consolidated University was formalized by law.

In the three-quarters of a century since its founding, the research, extension and academic programs at the institution have grown to embrace the work of more than 1,000 professional staff members, 16 branch agricultural experiment stations, eight undergraduate schools, agents in each of the state's 100 counties, and a $10 million annual research expenditure.

The main campus of 2,500 acres is valued at more than $50 million, and includes 75 major classroom, laboratory, and auxiliary facilities buildings.

As the programs for research and study have grown and become more complex, special institutes and curricula have been established. Prominent at NCS are the Institutes of Statistics, Biological Sciences, Water Resources, and Agricultural Policy and the Sensory Physiology Laboratory.

An interesting feature of the graduate program at State is the large number of international students. There are more than 350 foreign students —both graduate and undergraduate—studying at NCS. An International Student Center provides opportunity for students to become acquainted with future leaders of many countries.

Holladay Hall, the main administrative office building, is the oldest building on campus. Erected in 1889, two years after State was founded, the building is named in honor of Alexander Q. Holladay, first president of the college.

There are eight undergraduate schools at "State": Agriculture and Life Sciences, Design, Education, Engineering, Forestry, Liberal Arts, Physical Sciences and Applied Mathematics, and Textiles.

With its many concerts, lectures, and arts programs, its cosmopolitan character, and its broad research and educational commitments, North Carolina State provides an ideal academic and cultural climate for graduate study.

Cast in the mold of the modern, complex state university, North Carolina State also has responsibilities of international dimension. In addition to an extensive technical assistance program in Peru, "State" faculty conduct specialized projects throughout the world and host a continuing procession of international visitors.

THE GRADUATE SCHOOL OF THE UNIVERSITY OF NORTH CAROLINA

NORTH CAROLINA STATE DIVISION

DONALD B. ANDERSON, *Vice President, Academic Affairs, Chapel Hill*
WALTER JOHN PETERSON, *Dean, Raleigh*

The Graduate School of the Consolidated University of North Carolina is composed of three divisions, one at each of the three units of the University System. Each branch of the Consolidated Graduate School is administered by a graduate dean who works in close association with the Vice President in Charge of Academic Affairs. The Graduate Council is composed of representatives of the Administrative Boards of each of the three units of the Consolidated University. At North Carolina State the graduate dean is assisted in all matters of policy by an Administrative Board of ten members. Seven are elected by the faculties of the degree-granting schools and three are appointed by the Chancellor after consultation with the Dean.

Graduate instruction at North Carolina State is organized to provide opportunity and facilities for advanced study and research in the fields of agriculture and life sciences, engineering, forestry, physical sciences and applied mathematics, technological education, and textiles. The purpose of these graduate programs is to develop in advanced students a more adequate comprehension of the scope of knowledge in these special fields of learning and an understanding of the requirements and responsibilities essential for independent research investigations. In all of the graduate programs emphasis is placed upon a high level of scholarship rather than upon the satisfaction of specific course or credit requirements.

The full resources of the Consolidated University of North Carolina are available to all graduate students enrolled at any of the three divisions of the Graduate School. Exceptional facilities for graduate study are provided at North Carolina State. New buildings furnish modern well equipped laboratories for graduate study in specialized areas of agriculture and life sciences, engineering, forestry, physical sciences and applied mathematics, and textiles.

The North Carolina Agricultural Experiment Station and the Department of Engineering Research are integral parts of the University at Raleigh. The staff, research facilities, equipment, and field studies of these organizations contribute in a very important way to the graduate programs. The Institute of Statistics at North Carolina State makes available to graduate students unusual opportunities in this important phase of research study.

The State of North Carolina, extending from the Atlantic Ocean westward about 500 miles to the Appalachian Mountains, possesses an exceptional range of climatic and topographic environments. The Coastal Plain, the Piedmont, and the mountains provide a rich pattern of agricultural and industrial activities which offer unusual opportunities for research study and employment.

North Carolina State is located in Raleigh, situated on the boundary separating the broad coastal plains on the East from the rolling terrain of the Piedmont on the West, about midway between the northern and southern boundaries of the State. Raleigh is 29 miles from the University of North Carolina at Chapel Hill, and 26 miles from Durham, the home of Duke University. The libraries and other facilities of the three institutions make this area one of the important centers of research opportunity in the South.

The D. H. Hill Library

The D. H. Hill Library of North Carolina State has excellent holdings in materials essential for research study in the graduate curricula offered by the University.

As of July 1, 1963, the Library held about 270,000 volumes of books and bound journals, including more than 12,000 bound volumes of documents. The books and journals reflect strongly the scientific and technological interests of the University, and the documents represent a most important increment of the whole collection. They include publications of the Federal Government, all publications of the various Agricultural Experiment Stations, most of the publications of the Engineering Experiment and Engineering Research Stations, and publications of the various research stations all over the world.

The D. H. Hill Library holdings and other library holdings within a 30 mile radius of North Carolina State constitute the greatest concentration of library resources south of Washington, D. C. These include the D. H. Hill Library, the Chemstrand Research Center Library, the Duke University Library, and the Louis Round Wilson Library at the University of North Carolina at Chapel Hill.

An inter-library delivery service exchanges volumes among the three University libraries three days a week. These three libraries have a total of more than 3,000,000 volumes. This loan service serves faculty and graduate students on the three campuses. Identification certificates enabling participation in the reciprocal arrangement may be secured at the D. H. Hill Library.

The D. H. Hill Library is preparing a list of scientific periodicals which will list holdings of Duke University and the units of the Consolidated University. This will be available to faculty members and research scientists in the area and to other libraries throughout the Nation.

The North Carolina State Library is a depository for all unclassified publications of the Federal Government that are available for distribution. They include publications of the United States Department of Agriculture, Geological Survey, National Bureau of Standards, Department of Interior and others. Since the Library was designated as a depository in 1923, its document holdings in the University's special interest fields are almost 100 per cent complete.

The Library is a depository for the publications of the Carnegie Institution of Washington and has excellent files of these valuable monographs.

Also, the Library is a depository for all unclassified and declassified publications of the Atomic Energy Commission.

Publications of many foreign countries—especially publications dealing with the agricultural sciences and with engineering—are received on exchange by the Library.

In July, 1960, the Library became a depository for the publications of the Food and Agriculture Administration of the United Nations.

The Library, in July, 1959, acquired the Tippmann Collection of Entomology, the outstanding private collection of Dr. Friedrich F. Tippmann of Vienna. The collection contains 6,200 books and bound research journals in the field of entomology, many of them rare and unobtainable.

A recent donation of $5,000 from the Alumni Association was used to purchase two outstanding sets of the rare 20-volume "Edizone Nazionale" of the works of Galileo and an almost complete file of the important German botanical periodical, "Bibliotheca Botanica," covering the years 1889 to 1960.

Funds ($3,501) from the estate of the late Chancellor J. W. Harrelson were allocated to purchase 118 rare volumes in mathematics and history of science.

The research holdings of the Library are particularly strong in the fields of entomology, nuclear energy, genetics, aeronautics and space technology, engineering and physics, and include files of the major journals in these fields. A large and useful collection of books in the humanities and the social sciences is available for the use of undergraduate students.

The Library's photocopy service is of great importance to faculty and graduate students in that it provides facilities for copying materials not permitted to leave the library.

The Textile Library, an on-campus branch of the main library, contains outstanding holdings in textiles and textile chemistry. It is regarded as one of the best textile libraries in the country. The School of Design Library has a very fine collection of books, journals and slides in the fields of architecture, landscape architecture and product design.

Institute of Statistics

The Institute of Statistics is composed of two sections, one at Raleigh and the other at Chapel Hill. At North Carolina State, the Institute provides statistical consulting services to all branches of the Institution, sponsors research in statistical theory and methodology, and coordinates the teaching of statistics at the undergraduate and graduate level. The actual instructional and other academic functions are performed by the Department of Experimental Statistics, which forms a part of the Institute.

The purpose of the Institute is to provide extra depth and strength in the development and use of modern statistical procedures throughout the Institution. This involves cooperative efforts with many schools, departments, and agencies. The establishment of a nationally recognized program in quantitative genetics and recent developments in the field of biomathematics illustrates the coordinating role the Institute plays in the quantitative sciences.

In addition to these local activities, the Institute maintains close and continuing contact with statistics scholars, research programs, and graduate

instruction programs throughout the world. It has helped develop an international abstracting journal for statistical articles. The Institute is the point of contact for grants and contracts in statistics. It has been active in organizing and maintaining a strong Southern Regional Cooperative Graduate Summer Session in statistics. Approximately 15 graduate assistantships in statistics are made available annually through the efforts of the Institute. All of these contributions have added substantially to the vigor of the entire graduate program of North Carolina State.

Computing Facilities

The IBM 1410 Tape System in the Computing Center is available for graduate instruction and research. The Computing Center each year offers several non-credit short courses in FORTRAN programming to facilitate the use of this computer in graduate research.

One IBM 1620 Computer, used jointly by the Department of Agricultural Economics and the Biomathematics program, is available for use by graduate students in these areas. A second IBM 1620 is available for graduate students in the School of Textiles.

A LINC III Computer is available for research in the Biomathematics program.

Nuclear Reactor Project

The Nuclear Reactor Project at North Carolina State descends from the first privately-owned research reactor facility in the United States, installed at North Carolina State in 1952.

A 100-kilowatt tank-type heterogeneous reactor and supporting equipment are available for graduate research and laboratory study. Facilities are also available for studies in radiochemistry, nuclear physics, nuclear electronics, health physics, and neutron and gamma-ray spectroscopy.

Student, faculty, and contract research activities are concurrent with the instructional programs. This produces an atmosphere that is stimulating to the student and aids in keeping course material abreast of recent developments in the nuclear energy field.

Research Program at the Oak Ridge Institute of Nuclear Studies

North Carolina State is one of the sponsoring institutions of the Oak Ridge Institute of Nuclear Studies at Oak Ridge, Tennessee. Through this cooperative association, North Carolina State's graduate research program has at its disposal the facilities and research staff at Oak Ridge National Laboratory. Extensive research programs are underway there on physical and biological effects of radiation, radioisotope utilization, and many other areas of nuclear science and engineering. When master's and doctoral candidates have completed their resident work, it may be possible, by special arrangement, for them to do their thesis research at Oak Ridge. In addition, it is possible for the staff members of this University to go to Oak Ridge for advanced study in their particular fields.

Institute of Biological Sciences

The Institute of Biological Sciences is an organization within the School of Agriculture and Life Sciences of the Departments of Botany and Bacteriology, Entomology, Genetics, Plant Pathology, Zoology and faculties of Microbiology and Biochemistry. Its function is to encourage and promote research and teaching in basic biology and to coordinate inter-departmental activities. Program-type grants are administered by the Institute and enable grant support to be provided to discipline and subject matter areas involving faculties in several departments. Personnel from six departments and three schools are involved in research and graduate training.

Facility planning, development and support for biological sciences is an important function of the Institute. Also, Summer Institutes are administered in the Institute of Biological Sciences. These have included the National Science Foundation sponsored Summer Institutes in Genetics for College Teachers, Biology for High School Teachers and Biology, Chemistry, and Mathematics for High School Students.

Undergraduate Research Participation for Biological Sciences is a cooperative program administered in the Institute. This program has had an outstanding record in the percentage of individuals going into graduate study following their participation in this program.

This organization provides a mechanism for strengthening research and instruction in existing graduate programs and for developing new interdisciplinary areas. Inter-departmental cooperative graduate programs have become increasingly important within the basic biological sciences and between the biological, physical and engineering sciences. The Institute plays an important role in encouraging the full utilization of the faculties and facilities for graduate research and instruction.

Harrelson Hall's unusual architecture makes it a campus landmark as well as a most functional classroom building. Home of the newly created School of Liberal Arts, the building contains 112 offices and 77 classrooms, making it the largest classroom facility on campus.

ADMISSION

Graduate School admission may be to full graduate standing, provisional or unclassified status. Applications for admission to the Graduate School must be accompanied by official transcripts from all colleges previously attended.

Full Graduate Standing—For admission in this category a student must have a bachelor's degree from a recognized college or university regarded as standard by a regional or general accrediting agency and must have at least a B grade average in his undergraduate major.

Provisional admission may be granted to applicants who lack undergraduate work considered essential for graduate study in the major field. Course work, without graduate credit, will be required to make up such deficiencies before admission to full graduate status can be granted.

Graduates from non-accredited institutions may be granted provisional admission when their academic records warrant this status. Additional course work will be required of such students when deficiencies in their previous training are apparent.

Graduates from accredited institutions whose scholastic records are below the standards for admission to full graduate standing may be admitted provisionally when unavoidable extenuating circumstances affected their undergraduate averages or when progressive improvements in their undergraduate programs warrant provisional admission. All such students are required to take the Graduate Record Examination and to submit scores to the Graduate Office in support of their application. The National Teacher Examination may be substituted for the Graduate Record Examination if recommended by the department head. Information as to the dates on which the Graduate Record and the National Teacher Examinations are given may be obtained at the Graduate Office.

Graduate students admitted on a provisional status may attain full graduate standing when the deficiencies responsible for their provisional status are corrected. They also must have maintained a satisfactory academic record in all course work taken as part of their graduate program. Change from provisional to full graduate standing is effected only on written recommendation from the department in which the student is seeking his degree.

Unclassified graduate students are not candidates for graduate degrees. They may take courses for graduate credit, but may not apply more than ten credits earned while in the unclassified status to any program leading to an advanced degree at this institution. Unclassified graduate students are expected to meet the same admission requirements that apply to graduate students in full standing.

Applications for admission to the Graduate School should be on file in the Graduate Office at least thirty days in advance of the registration date for the term in which the student wishes to enroll in the Graduate School.

Public school personnel (primary teachers, secondary teachers, or administrators) registering at North Carolina State for the first time who are interested primarily in "Certification Credit" may enroll as graduate students for a maximum of six semester hours without forwarding official transcripts of previous work to the Graduate Office. If, however, application is not made through normal channels for graduate credit in the session in which the

course or courses are taken, the student will not be permitted to apply the credit toward an advanced degree at North Carolina State, or elsewhere.

In all cases where the teacher's interest is primarily in approval for certification credit, the School of Education will be responsible for assessing the adequacy of the teacher's qualifications for enrollment in the University in the particular course or courses. The School of Education will also be responsible for advising all such students early in each school session that if they wish their credits to be applied in due course to a higher degree at North Carolina State, or elsewhere, normal admission procedures will be required.

All teachers who have previously attended North Carolina State and earned six semester hours of credit and wish to enroll for additional courses for graduate credit will be required to make application for admission to the Graduate School in the usual manner, if they have not already done so.

In all cases a "B" level of academic performance or better is required.

Graduate-Special—This classification is used primarily for students enrolling in special institutes such as the summer institutes regularly held for college teachers, high school teachers, and graduate students, or special graduate training programs for separate groups such as our summer offerings for extension staff.

The following rules apply to students registered as Graduate-Special:

1. All must have at least a baccalaureate degree from an accredited institution of higher learning.
2. Official transcripts need not be submitted to the Graduate Office for enrollment in this classification but the appropriate Institute or Program Director must file with the Graduate Dean well in advance the nature of the program, the criteria and methods used in selection of the students, and assurances that the students have adequate preparation for the courses contemplated.
3. Placement in this classification carries with it no implication that students will be admitted to the Graduate School in any of the other classifications.
4. Graduate credit will be allowed for not to exceed six hours of course work at the 500 or 600 level if performance is at a "B" level or better.
5. If the student is in due course admitted to the Graduate School, graduate credit obtained under this classification may apply to an advanced degree, if in the judgment of the Advisory Committee the course (s) are germane to the particular program of work.
6. Students who have received as much as six hours of graduate credit under this classification must make application for admission to the Graduate School before permission will be granted to enroll for additional graduate work.

Registration—The Office of Registration must have written authorization from the Dean of the Graduate School before any graduate student will be given a permit to register. This authorization will be sent to the Office of Registration by the graduate dean at the time the student is notified of his acceptance.

Physical Examinations—All regularly enrolled graduate students must take a physical examination preferably given by the family physician and the

results recorded on forms provided by the University. When this is not done the examination may be given by the N. C. State physician during registration for a fee of $5.00.

Course Load—A full-time graduate load is considered to be nine to fifteen credits per semester. This course load restriction is made so that graduate students may have time for reading and contemplation well beyond the limits set for satisfactory undergraduate work. In exceptional cases one or two additional credit hours may be added to the roster if necessary in order to get prerequisite work which is not taught in subsequent terms, provided the corresponding adjustment in course load is made in the other terms. Rosters with additional credit hours beyond fifteen should be accompanied by a special note from the head of the major department indicating the reasons for the additional work.

Full-time employees may register for credit or audit one course in each semester upon the recommendation of their department head and approval of their dean and the business manager.

Employees having academic rank higher than that of instructor may register for graduate work for credit to be transferred to other institutions. They may not undertake programs for graduate degrees in the Consolidated University of North Carolina.

Graduate assistants on half-time appointments are permitted a maximum course load of nine credits per semester unless corresponding adjustments are made in their service obligations during the same semester. If the appointment is for the academic year of nine months, half-time assistants are restricted to a maximum of eighteen credit hours of work during the nine months of their appointment. Half-time graduate assistants whose appointments are for twelve months may not exceed a total of twenty-four credits during the twelve month period of their appointment. Three-quarter time graduate assistants whose appointments are for twelve months may register for a total of sixteen credits during the calendar year. A total of six credits is the maximum load in a regular semester.

A member of the North Carolina State senior class may, upon approval of the Dean of the Graduate School, register for courses in the 500 group for graduate credit to fill a roster of studies not to exceed fifteen credits in any semester. Not more than six hours of graduate credit may be acquired by an undergraduate student. Courses listed with numbers in the 600 series are not ordinarily open to undergraduates. Occasional exceptions may be made for "honor" students.

GRADUATE DEGREES

Admission to the Graduate School does not constitute admission to candidacy for a graduate degree. Application for admission to candidacy for graduate degrees must be submitted to the Administrative Board of the Graduate School. Applications of students preparing for the master's degree may not be filed before the satisfactory completion of one full semester of graduate study and must be presented before the end of the first week of the last semester in residence. Approval of the application will be determined by the quality of the scholastic record and on the certification by the major depart-

ment that the student is qualified to continue advanced work. Admission to candidacy for the doctorate is granted upon satisfactory completion of the qualifying or preliminary examinations.

The Graduate School at North Carolina State offers work leading to the Master of Science degree and the Professional Master's degree in certain specialized fields in the Schools of Agriculture and Life Sciences, Education, Engineering, Forestry, Physical Sciences and Applied Mathematics, and Textiles; and the Doctor of Philosophy degree in certain fields of agriculture and life sciences, engineering, forestry, and physical sciences and applied mathematics.

A graduate student is expected to familiarize himself with the requirements for the degree for which he is a candidate and is held responsible for the fulfillment of these requirements. This applies to the last dates on which theses may be accepted, the dates for examinations, the proper form of theses, and all other matters regarding requirements for degrees.

Master of Science Degree

The Master of Science degree is awarded at North Carolina State after a student has completed a course of study in specialized fields in agriculture and life sciences, education, engineering, forestry, physical sciences and applied mathematics, or textiles; demonstration of ability to read a modern foreign language; completion of a satisfactory thesis and of comprehensive examinations in the chosen field of study.

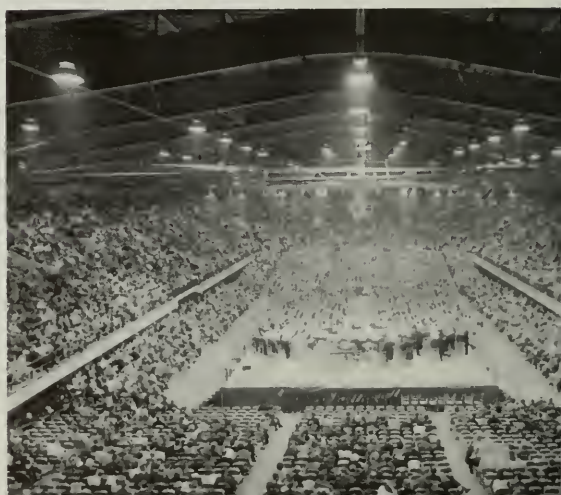
In addition to complying with these requirements, the candidate for the Master of Science degree is expected to achieve high levels of scholarship. Graduate study is distinguished from undergraduate work by its emphasis upon independent research. The graduate student is more interested in the significance of facts than in the accumulation of data. He is concerned with the materials of learning and the organization and interpretation of these materials.

A graduate student's program of study is planned so as to provide a comprehensive view of some major field of interest and to furnish the training essential for successful research in this field and related areas of knowledge. As great a latitude is permitted in the selection of courses as is compatible with a well-defined major interest. The program of course work is selected with the object of making possible a reasonable mastery of the subject matter in a specialized field. Training in research is provided to familiarize the student with the methods, ideals, and goals of independent investigation. Since there are many possible combinations of courses, the administration of graduate programs calls for personal supervision of each student's plan of work by a special advisory committee of the graduate faculty. (See page 23). The program of course work to be followed by the student as a part of the requirements for the master's degree and the thesis problem selected must be approved by the student's advisory committee and the Dean of the Graduate School.

The Erdahl-Cloyd Union is both the sponsor and the center for a broad range of concerts, lectures, and exhibits, ranging from an undergraduate experimental theater to appearances by international figures. Madame Nhu addressed an overflow student audience, the press, and the public (over WUNC-TV, the educotional TV station) from the Union.

The Union Gallery, now celebrating its 10th year anniversary, features outstanding exhibits in art, design, crafts, and photography. The Gallery is staffed by a volunteer committee, comprised of students in many academic fields, and provides exhibitions throughout the year.

World renowned artists, presenting concerts under the auspices of "The Friends of the College, Inc." sponsored by the Union, attract upwards of 12,000 persons. This is the Leningrad Philharmonic. Students are automatic members of the concert organization.



Credits

1. For the Master of Science degree a minimum of 30 semester credits is required.
2. No more than six of the academic credits required for the degree will be accepted from other institutions.
3. No graduate credit will be awarded for excess undergraduate credit from another institution.
4. All work credited toward a master's degree must be completed within six calendar years.
5. No graduate credit is allowed for courses taken by correspondence. A maximum of six semester credits may be obtained in extension study in the field of education provided the extension courses are taught by a member of the graduate faculty and provided the courses are given graduate ranking by the Graduate School. Courses taken by extension are accepted for graduate credit only when the student has been admitted to the Graduate School and when notice of his registration is filed with the Graduate Office. Credit for extension courses reduces the amount of credit that may be transferred from other institutions by the amount of graduate credit granted.

The thirty semester credit hour requirement for the master's degree represents the minimum quantity of work acceptable. The credit hours required of graduate students usually exceed the minimum requirements. Inadequate preparation and thesis research frequently make additional work necessary.

Courses of Study

The program of the student shall include at least eight semester credits in courses of the 600 group, no more than six of which may be allowed for research study. At least twenty semester hours must come from the 500 and 600 group. A maximum of two hours of seminar is permitted.

During the first term in residence an advisory committee of at least three faculty members, one representing the minor field, will be appointed by the dean, after consultation with the head of the major department, for each student engaged in a program of work leading to the master's degree. The advisory committee will meet with the student and prepare a program of course work to meet the requirements of the student's graduate objectives. Four copies of the program, prepared on forms provided for this purpose, must be approved by each member of the committee, by the head of the major department, and by the Dean of the Graduate School. After approval in the Graduate Office, three copies will be returned to the department head—one for his files, one for the chairman of the advisory committee, and one for the student.

The courses taken by a graduate student shall constitute a well rounded but unified plan of study. This means that the program of research and course work shall be divided between a major and a minor field. While there are no inflexible rules which govern the number of credit hours that must constitute the major and minor, in general, it is expected that approximately

two-thirds of the course work will fall in the major and one-third in the minor. The detailed course requirements for each graduate student program are left to the judgment of the advisory committee.

Residence

Students engaged in a course of study leading to the Master of Science degree are required to be in residence, pursuing graduate work, one full academic year.

Class Work

A graduate student is expected to show greater initiative in exploring the possibilities of the subject matter presented in the courses he takes than is the undergraduate. He is also expected to recognize the significance of facts and to assume a responsibility for relating data to theoretical concepts. In preparation, attendance, and in all the routine of class work the graduate student is subject to the regulations observed in other divisions of the University.

Grades

A minimum grade of "C" must be made on all formal course work to obtain graduate credit. An average of "B" must be obtained on all course work taken as a part of the student's graduate program. Failure to maintain a "B" average in any term will place the student on probation. Any student whose academic record fails to meet the "B" average requirement for two consecutive terms will not be permitted to continue a graduate program without the written approval of the graduate dean.

Grades in research, seminar, and special problem courses are given in terms of "S" (*satisfactory*) or "U" (*unsatisfactory*) in place of the symbols used for formal course work.

The grade *incomplete* may be used in research and laboratory courses when circumstances beyond the control of the student have prevented completion of the work by the end of the academic term. A grade of *incomplete* may be given only after approval by the graduate dean and must be converted to one of the usual symbols before the end of the next academic semester in which the student is in residence.

Language Requirements

A reading knowledge of at least one modern foreign language (Germanic, Romance, or Slavic) is required of candidates for the Master of Science degree.

The language requirement must be satisfied before a student can be admitted to candidacy.

Proficiency in languages is determined by the Department of Modern Languages:

1. By traditional reading knowledge examination at any time requested by the student.

2. By taking course work (audit) especially designed for graduate students who have no previous foreign language experience or who wish to refresh work formerly done. The department offers special courses beginning with elementary grammar and proceeding in the course of the semester to general scientific reading. Pronunciation is emphasized to the degree to which it will help in translating from the language into English. This first course is followed by a second course in which the student selects work from scientific publications touching as nearly as possible his major interest. He will then be assigned a particular instructor with whom he will read in individual conferences. When the conference instructor is satisfied that the student has demonstrated his knowledge of intricate grammatical problems, a decrease in the time required for reading, and a confidence in his ability to use the language, he will be certified without further examination. The completed translations may then, depending upon their merit, be edited and prepared for permanent filing with the various translation libraries throughout the country.

Graduate students who expect to complete the requirements for the Master of Science degree should confer with the Head of the Department of Modern Languages soon after registration to formulate plans for meeting the language requirement of this degree.

Students whose native language is other than English may meet the foreign language requirement for the Master of Science degree by demonstrating a satisfactory mastery of English. Examinations in English are conducted by the English Department.

Thesis

A candidate for the Master of Science degree must prepare a thesis representing an original investigation. The subject of the thesis must be approved by the head of the department in which the major work is done and by the student's advisory committee. Three copies of the thesis in final form and five copies of the abstract must be filed in the Graduate Office at least one month before the degree is awarded. Detailed instructions as to form and organization of the thesis may be obtained at the Graduate Office.

Examinations

All candidates for the Master of Science degree must pass, with a grade of "A", "B", or "C", all formal course work specified as part of the requirements for the degree. Graduate credit for research, seminar, and special problem courses is granted when a grade of "S" is recorded in the Registration Office. In addition, the candidate must pass a comprehensive oral examination that is held to satisfy the examining committee that the candidate possesses a reasonable mastery of knowledge in the major and minor fields and that this knowledge can be used with promptness and accuracy. This examination may not be held until all other requirements, except completing the course work of the last semester, are satisfied. Application for the comprehensive oral examination must be filed with the graduate dean by the chairman of the

advisory committee at least two weeks prior to the date on which the examination is to be held.

The oral examination will be conducted by an examining committee appointed by the graduate dean. The chairman of the examining committee will be the chairman of the student's advisory committee. At least two additional members will be appointed to represent the major and minor fields. The comprehensive oral examination is open to all faculty members who care to attend but the decision as to the candidate's fitness rests solely with the examining committee.

At the discretion of the examining committee, written examinations covering the subject matter in the major and minor fields also may be required of the candidate. Written examinations, when required, may not be held earlier than the end of the first month of the last semester in residence, and not later than one week before the comprehensive oral examination.
See Summary of Procedures for the Master's Degree below.

Master's Degree in a Professional Field

This degree is offered for students who are interested in the more advanced applications of fundamental principles to specialized fields rather than in the acquisition of the broader background in the advanced scientific studies which would fit them for careers in research. Students working for this degree ordinarily will terminate their graduate work at this point.

Examples of the types of degrees that may be awarded upon the completion of the course of study in a professional field are Master of Education, Master of Forestry, Master of Agricultural Engineering, Master of Applied Mathematics, Master of Experimental Statistics, Master of Electrical Engineering, and Master of Textile Technology.

The chief characteristic of these degrees is that the changes made in requirements permit, in greater measure, the satisfaction of what are represented as professional needs than do the requirements for the conventional Master of Science degree.

Language Requirements

The candidate for a master's degree in a professional field is exempt from the requirement of a reading knowledge of a modern foreign language.

Thesis Requirements

In the School of Education the thesis requirement for the master's degree in each of the specialized fields may be waived by the department in which the degree is sought. When the thesis requirement is waived the student must complete the course "Introduction to Educational Research," or a departmental course in research and a problem report. A thesis is required for the professional degree in the departments of the School of Agriculture and Life Sciences. A thesis is not required in the Master of Forestry, Master of Applied Mathematics, Master of Experimental Statistics, Master of Electrical Engineering and Master of Textile Technology programs.

Other Requirements

The other requirements for the master's degree in a professional field are the same as for the Master of Science degree.

Master of Agriculture Degree

This plan is offered for the students who are interested in advanced training in the broad field of agriculture but whose responsibility is not in research. The requirements for the degree are designed to provide an opportunity for professional training without narrow specialization for those who plan to devote their lives to some phase of practical agriculture. Among the individuals interested in this degree are agricultural extension workers and foreign students who are in action or educational programs. The proposed plan differs from the plan for the Master of Science degree in the following principal respects:

1. A total of thirty-six semester credits is required.
2. A minimum of four semester credits in special problems is required. Not more than six semester credits in special problems will be allowed. This work replaces the research thesis requirement for the Master of Science degree.
3. There are no specific requirements as to courses in the 600 group.
4. A reading knowledge of a modern foreign language is not required.

In all other respects the requirements for the Master of Agriculture degree are the same as those for the Master of Science degree.

A Summary of Procedures for the Master's Degree

1. Letter of inquiry from prospective student to Graduate School or department head.
2. Mailing of proper forms to student by Graduate School or department head.
3. Receipt of application form and transcript by Graduate School.
4. Application with transcript sent to department head for study.
5. Department head recommends acceptance of prospective student stating curriculum in which he will work and the degree sought.
6. Assuming the prospective student meets the minimum scholastic standards, notice of acceptance is mailed to him by the Graduate School. When the student's academic record fails to meet the minimum scholastic standards of the Graduate School, provisional admission may be granted upon submission by the student of evidence of a satisfactory performance on the Graduate Record or National Teacher Examinations. The National Teacher Examination is accepted only when approved by the department head and the graduate dean.
7. Permit to register is sent by the Graduate School to the registrar.
8. Student arrives, reports to the department head, is assigned an advisor and makes out a roster of courses in consultation with departmental advisor.

9. Advisory committee of three or more faculty members, one of whom represents the minor field, appointed before the end of the first semester of graduate study by the Graduate School after consultation with the department head.
10. Plan of work prepared by the advisory committee in consultation with the student and submitted in quadruplicate to the Graduate School by the end of the first semester in residence.
11. Plan of work approved by the graduate dean and three copies returned to the department head. One copy is kept in department files, one goes to the advisor, and one is given to the student.
12. A thesis subject is selected and an outline of the proposed research submitted to the department head and to the student's advisory committee. Students preparing themselves for the professional degree in specialized fields of education should consult the chairman of their committees with reference to their problem report.
13. Student passes language examination. Students preparing themselves for the master's degree in a professional field are not required to pass a language examination. The language requirement must be satisfied before admission to candidacy can be granted.
14. Student applies for admission to candidacy for the master's degree. Application must be filed before the end of the first week of the last semester in residence and may not be filed before the language requirement is satisfied.
15. Application is reviewed by the head of the major department and by the graduate dean and if approved the student becomes a candidate for the degree.
16. A copy of a preliminary draft of the thesis is submitted to the chairman of the student's committee for criticism.
17. At least two weeks prior to the final oral examination, the chairman of the student's advisory committee submits a corrected draft of the dissertation to members for review.
18. Permission for the candidate to take the final oral examination is requested of the Graduate School at least two weeks before the examination and must be accompanied by a certification that the thesis is complete except for such revisions as may be necessary as a result of the final examination.
19. Permission is granted by the graduate dean—date is set and examining committee appointed. The report on the final examination should be filed with the Graduate School as soon as the examination has been completed.
20. Three copies of the thesis in final form approved by each member of the student's advisory committee and signed by the advisor must be submitted to the Graduate School at least four weeks before the end of the semester or summer session in which the degree is to be conferred.
21. Graduate School certifies to the Registration Office and to the general faculty that all requirements for the degree have been met and recommends the awarding of the degree.
22. Student must be registered in term in which degree is to be awarded.

Memorial Tower, located at the main entrance to the campus, has become the traditional symbol of North Carolina State. The 122 foot tower, built in memory of State alumni lost in World War I, is equipped with carillon bells which ring out the alma mater three times daily.

Doctor of Philosophy Degree

The degree of Doctor of Philosophy is offered in the following departments:

Agricultural Economics
Agricultural Engineering
Animal Science
Applied Mathematics
Applied Physics
Botany and Bacteriology (in the fields of bacteriology, physiology and ecology)
Chemical Engineering
Civil Engineering
Crop Science
Electrical Engineering
Entomology
Experimental Statistics
Food Science
Forestry
Genetics
Mechanical Engineering

Mineral Industries (in the field of ceramic engineering)
Nuclear Engineering
Physiology
Plant Pathology
Rural Sociology
Soil Science
Zoology (in the fields of ecology and wildlife biology)

The doctor's degree symbolizes the fact that the recipient is capable of undertaking original research and scholarly work at the highest levels without supervision. Therefore, the Doctor of Philosophy degree is not granted on a basis of the successful completion of a given amount of course work, but rather upon the demonstration by the candidate of a comprehensive knowledge and high attainments in scholarship and research in a specialized field of study. These attainments are determined by the quality of the dissertation which the candidate prepares to report the results of original investigations and by passing successfully a series of rigorous and comprehensive examinations on the special and related fields of study.

Course of Study

At the time of admission the student should, with the advice of the chairman of the department, elect a major field. During the student's first semester in residence, an advisory committee of at least four members will be appointed by the graduate dean, after consultation with the department head, to prepare with the student a plan of graduate work. Four copies of the program, signed by all members of the advisory committee and the department head or graduate administrator, are referred to the graduate dean for approval. When approved three copies are returned to the department head, one being retained in the department files, a second copy is given to the chairman of the advisory committee, and the third copy is given to the student. The subject of the dissertation must appear on the plan of work and any subsequent changes in the subject of the thesis or in the plan of graduate work must be reported to the Graduate School for approval.

There are no definite requirements in credit hours for the doctor's degree. Emphasis is placed upon a comprehensive knowledge of a well defined and recognized field and related subjects. Each student will have a major and one or two minor areas of specialization. The minor field ordinarily will consist of at least twenty semester credit hours. These may fall in an allied department or in the major department. A minor in the department of the major is permitted only when the department offers recognized divisions of study other than that designated as the major field.

Residence

For the Doctor of Philosophy degree, the student is expected to be registered for graduate work for at least six semesters beyond the bachelor's degree at some accredited graduate school. The amount of work from other institutions credited to the fulfillment of degree requirements will be determined by the dean after consultation with the student's advisory committee at the time the plan of graduate work is filed.

At least two residence credits, as defined below, must be secured in continuous residence (registration in consecutive semesters) as a graduate student at some branch of the Consolidated University of North Carolina. Failure to take work during the summer does not break the continuity; however, summer school work can be used to fulfill this requirement.

Residence credit is based on the number of credits of graduate work beyond the bachelor's degree carried in a given term. During a regular semester, residence credit is calculated in the following manner:

Semester Credits	*Residence Credits*
9 or more	1
6 - 8	2/3
less than six*	1/3

The residence credit for a six-week summer term is only one-half the corresponding amount for a regular semester; i.e., six semester credits carry 1/3 residence credit and less than six credits, 1/6 residence credit. If a student registers for a twelve-week summer term, the residence credit is computed as for regular semesters. If a student registers for both twelve-week and six-week summer terms, the residence credit is computed separately for each type and totaled, with the stipulation that no more than one residence credit can be earned in a given summer.

The candidate must complete all requirements for the degree, including the final examination on his dissertation, within a period of seven calendar years from the date of admission to candidacy for the degree.

Languages

A reading knowledge of scientific literature in two modern foreign languages or a comprehension in depth of one language is required for the Doctor of Philosophy degree.

Comprehension in depth is to be interpreted as a proven ability in the oral and composition elements of a particular language as well as the reading knowledge normally required. Ph.D. students desiring to offer one language in depth should consult with the Head of the Modern Languages Department as to the specific courses to be followed to achieve this comprehension. Specific arrangements may differ depending upon the student's previous background in the language. It is emphasized that students choosing to achieve competence in depth in one language will generally find this alternative more rigorous than proof of reading ability in two languages.

If the student elects to work in two languages, the languages may be a combination of Romance and Slavic, Romance and Germanic, or Slavic and Germanic.

Students whose native tongue is some language other than English may use English as one of the languages required for the Doctor of Philosophy degree. When English is submitted in partial fulfillment of the language requirements, the native language may not be used to satisfy one of the language requirements.

* Including registration for thesis preparation on campus.

Examinations in English will be given by the English Department, and a statement certifying the candidate's proficience in English must be filed in the Graduate Office before the qualifying examination may be taken.

The Dissertation

The doctoral dissertation presents the results of the candidate's original investigations in the field of his major interests. It must represent a contribution to knowledge, adequately supported by data and written in a manner consistent with high standards of excellence in scholarship. Detailed instructions relating to the thesis may be obtained from the Graduate Office.

Publication of the results obtained in the thesis investigation is expected. Each copy of the thesis must be accompanied by an abstract of approximately 500 words.

The dissertation will be examined by all members of the examining committee and must receive their approval to be acceptable to the Graduate Office.

Two copies of the dissertation in final form and signed by all members of the student's advisory committee must be presented to the Graduate School not later than four weeks before the date on which the degree is to be awarded.

North Carolina State now has an agreement with University Microfilms, Inc., of Ann Arbor, Michigan, by which all doctoral dissertations are microfilmed and abstracts of the dissertations are published in *Dissertation Abstracts.*

Examinations

Not earlier than the end of the second year of graduate study and not later than the end of the third week of the academic year in which the degree is expected, each doctoral student is required to pass general comprehensive examinations (known as the qualifying or preliminary examinations). If summer sessions are involved, the interval between the date of the qualifying examinations and anticipated date of the awarding of the degree may be interpreted as including two consecutive summer sessions and one academic semester. The examinations are given by an examining committee of graduate faculty members appointed by the graduate dean after consultation with the head of the department in which the student's major work has been taken. The examining committee usually consists of the student's advisory committee and a representative of the Graduate School, but may include other members of the graduate faculty. The examinations are open to all members of the graduate faculty who may care to attend.

Authorization for the qualifying examination is requested of the Graduate School by the chairman of the student's advisory committee when the major part of the student's program of course work has been completed and when, in the judgment of the committee, the student is prepared to devote the greater part of his time to the prosecution of his research study. Members of the examining committee will be notified of their appointment by the Graduate Office. Official printed forms will be supplied to the chairman of the examining committee for a report of the results of the examination.

The examination consists of two parts: (1) written examinations prepared separately by each member of the examining committee and (2) an oral examination held before the entire examining committee. Upon receiving authorization for holding the qualifying examination, the chairman of the examining committee will request examination questions from each member of the examining committee. Each set of questions will be given to the student by the chairman of the examining committee in any order that may seem appropriate. The questions together with the student's answers will be returned to the members of the committee for grading. The questions may cover any phase of the course work taken by the student during the period of his graduate study or any subject logically related and basic to an understanding of the subject matter of the major and minor areas of study. They should be designed to measure the student's mastery of these subject matter fields and the adequacy of his preparation for research investigations.

Upon satisfactory completion of the written examinations the student must pass an oral examination before the entire examining committee. This examination is usually held within a week after the chairman of the examining committee has certified to the Graduate School that the student has completed satisfactorily the written examinations. The members of the examining committee will be notified by the Graduate School of the time and place arranged for the oral examination. The oral examination is designed to test the student's ability to relate factual knowledge to specific circumstances. In the oral examination the student is expected to use his knowledge with accuracy and promptness and to demonstrate that his thinking is not limited to the facts learned in course work.

When the examining committee consists of four members, a unanimous vote of approval is required for passing the preliminary examination. Approval may be conditioned, however, upon the completion of additional work in some particular field to the satisfaction of the committee. In case a single dissenting vote is cast in a four member committee, the course of action to be taken will become a matter for decision by the Administrative Board. Upon receiving the approval of the examining committee the student is admitted to candidacy for the doctorate.

A final oral examination is also required. During a normal academic year, an interval of at least eight months must elapse between admission to candidacy and the final oral examination. If summer sessions are involved, this interval may be interpreted to include two consecutive summer sessions and one academic semester.

This examination is held after the dissertation has been completed and consists of a defense by the candidate of the methods used and the conclusions reached in his research study. The examination is conducted by an examining committee. The examining committee usually includes the student's advisory committee, plus a representative of the Graduate School, although this procedure is not always adopted. The examining committee is appointed by the graduate dean after consultation with the head of the student's major department.

Failure of a student to pass either the preliminary or the final examination terminates his graduate work at this institution unless otherwise recommended

by the examining committee. No re-examination may be given until at least one full semester has elapsed since the first examination. Only one re-examination is permitted.
See Summary of Procedures for Doctor of Philosophy Degree below.

Admission to Candidacy

A student is admitted to candidacy after he has successfully passed the preliminary examinations. The language requirements must be fulfilled before permission to take the preliminary examination is granted. Admission to candidacy must be obtained before the end of the third week in the academic year in which the degree is expected; i.e., nearly two semesters before the degree is awarded.

Additional Information

A booklet containing detailed instruction about the form of dissertation may be obtained from the Graduate School.

Further information concerning graduate work at North Carolina State may be secured from *Dr. Walter J. Peterson, Dean of the Graduate School, North Carolina State of the University of North Carolina at Raleigh, Raleigh, N. C.*

Summary of Procedures for Doctor of Philosophy Degree

1. Letter of inquiry from prospective student to Graduate School or department head.
2. Mailing of proper forms to student by Graduate School or department head.
3. Receipt of application forms by Graduate School.
4. Application with transcript sent to department head for study.
5. Department head recommends acceptance of prospective student stating curriculum in which he will work.
6. Assuming the prospective student meets the minimum scholastic standards, notice of acceptance is mailed to him by the Graduate School.
7. Permit to register is sent by Graduate School to the registrar.
8. Student arrives, reports to the department head, is assigned an advisor, and makes out a roster of courses in consultation with departmental advisor.
9. Advisory committee of at least four members is appointed in the first term of graduate study by the graduate dean after consultation with the department head.
10. Plan of work prepared by the advisory committee in consultation with the student and submitted in quadruplicate to the Graduate School by the end of the first semester in residence.
11. Plan of work approved by the graduate dean and three copies returned to the department head. One copy is kept in department files, one goes to the advisor, and one is given to the student.
12. A dissertation subject is selected and an outline of the proposed research submitted to the department head and the student's advisory committee.
13. Student passes language examinations.

14. The chairman of the student's advisory committee requests permission to hold the qualifying examination. This must be done not earlier than the end of the second year of graduate study and not later than eight months (two semesters or one semester and two summer sessions) before the date on which the degree is to be awarded.
15. Permission to take qualifying examination granted by graduate dean if the student's record is in order. A date is set and examining committee appointed. The examination consists of two parts—a written and an oral.
16. A report of the examination is sent to the Graduate School. If the report is favorable, the student is admitted to candidacy.
17. A copy of a preliminary draft of the dissertation is submitted to the chairman of the student's committee for criticism.
18. At least two weeks prior to the final oral examination, the Chairman of the student's advisory committee submits a corrected draft of the dissertation to members for review.
19. Eight months (or two terms) after admission to candidacy or later, permission for the candidate to take the final oral examination is requested of the Graduate School by the Chairman of the candidate's advisory committee. Requests should be filed at least two weeks before the date of the examination and must be accompanied by a certification that the thesis is complete except for such revisions as may be necessary as a result of the final examination.
20. Permission is granted by the graduate dean if the student's record is in order. A date is set and examining committee appointed. The report on the examination should be filed with Graduate School as soon as examination has been completed.
21. Two copies of the thesis in final form must be submitted to the Graduate School not later than four weeks before the date on which the degree is to be awarded. It must carry the signatures of all members of the examining committee.
22. Graduate School certifies to the Registration Office and to the general faculty that all requirements for the degree have been met and recommends the awarding of the degree.
23. Student must be registered in the term in which the degree is to be awarded.

TUITION AND FEES

Tuition rates for students enrolled in the Graduate School at North Carolina State are as follows:

North Carolina resident—$9 per semester hour for each semester hour of enrollment up to and including nine semester hours. For ten semester hours or more, $87.50 for the semester.

Non-resident—$32 per semester hour for each semester hour of enrollment up to and including nine semester hours. For ten semester hours or more, $300 for the semester.

Incidental fees and charges are levied for purposes and services available to all graduate students whether or not the student takes advantage of them.

The full amount of incidental fees and charges will be collected, notwithstanding the number of semester hours of credit for which the student may enroll.

For the academic year 1964-65, fees are as follows.

First semester	$73
Second semester	$67

In cases of occasional or part-time graduate students not in residence application for cancellation of non-academic fees may be made if it is clear that the student could not use the services covered. Application forms are available in the Graduate School and the Office of Business Affairs.

Full-time staff or faculty members may be permitted to take one course per semester on the North Carolina State campus at a rate of $9 per semester hour plus a $7 registration fee or to audit one course at a charge of $17.00, in either case upon the recommendation of their department head and approval of their dean and the Business Manager. This payment does not include non-academic fees, and none of the privileges attendant upon the payment of such fees is allowed. Forms for this approval are available in the Office of Business Affairs. A maximum of 8 semester hours may be taken during the academic year.

Faculty members on less than full-time appointments will be permitted to take more than one course per semester upon the recommendation of their dean and the approval of both the Dean of the Graduate School and the Dean of the Faculty. In these cases tuition and fees will be the same as those for part-time graduate students computed at residence rates.

Maximum permissible course loads for graduate students holding part-time appointments are as follows: Three-quarters time, six hours; half-time, nine hours; quarter-time, twelve hours.

Students wishing to visit classes without participation in class discussions, quizzes, or examinations must register for this privilege as auditors. *Visiting classes without registration is not permitted.* Graduate students may register for one course as an audit in any semester without charge when the audit is certified by the Dean of the Graduate School as a part of course work for which tuition charges are made (this does not apply in the summer sessions).

Audits in subjects in which the student has had no previous experience will be evaluated at full credit value in determining course loads. Audits taken as repetition of work previously accomplished are considered at one-half their credit value in calculating course loads. With the single exception of foreign language audits, all audit registrations must fall within the maximum permissible course loads. Audits are not permitted students registering for thesis preparation. While audit registrations are evaluated for purposes of determining permissive course loads in terms of the above regulations of the Graduate School, the Office of Business Affairs considers all audits, excepting the one permitted free of charge, in terms of full credit value in calculating the tuition for graduate students.

All graduate students holding appointments of 1/3 service obligation or more and receiving a regular monthly salary check are charged the resident or "in-state" rate of tuition.

Graduate students who have completed all course work and residence requirements and who are in residence for the purpose of writing a thesis or dissertation may register for "thesis preparation." The tuition charge for this registration is $15. Students registering for thesis preparation will pay, in addition, fees of $73 in the fall semester and $67 in the spring semester.

Graduate students not in residence who have completed all requirements for the degree sought, including the thesis and final examination, will be required to register for "degree only" in the semester in which the degree is awarded. The charge for this registration is $10.

A diploma fee of $12 is charged all students receiving a master's degree and a fee of $17 is charged all students who receive a doctorate. A fee of $21 is charged all doctoral candidates for microfilming their dissertations.

Anyone who feels a mistake has been made in his bill may discuss the matter with the Office of Business Affairs. Any further appeals should be made to the Committee on Refund of Fees. Forms for this appeal may be obtained from the Office of Business Affairs.

All tuition charges and fees are subject to change without notice.

Fees for Summer School

Registration Fee	$11.00
Tuition (In-State Students per credit hour)	$ 7.50
Tuition (Out-of-State Students per credit hour)	$18.50
Audits (per credit hour)	$ 7.50

In order to draw a clear line between in-state and out-of-state students, the Administration has ruled that all students whose parents have not been domiciled in North Carolina for more than six months immediately preceding the day of their first enrollment in the institution shall be termed out-of-state students, with the following exceptions.

(1) Students twenty-one years of age at the time of their first matriculation who have resided in North Carolina for more than one year preceding the day of their first enrollment;

(2) Children of regular employees of the Federal Government stationed in the State of North Carolina; and

(3) Children of regular employees of the Federal Government who are employed outside of the State, but who through law are permitted to retain their North Carolina citizenship.

Students cannot claim a change in their resident status after matriculating. Students furnishing incomplete or incorrect information in order to obtain the special State-resident status shall be liable for dishonorable dismissal.

Graduate students employed by the University or the Experiment Station on a part-time basis are not permitted to register for a full-time load of course work. The Veterans Administration will classify such students as full-time students when it is officially certified by the Dean of the Graduate School that the students are engaged in a full-time program of professional work.

FELLOWSHIPS AND GRADUATE ASSISTANTSHIPS

Fellowships

Graduate fellowships are funds offered to graduate students to assist in the support of programs of advanced study. Holders of fellowships have no service obligations to the University and may devote full time to the prosecution of their graduate programs.

Some of the agencies sponsoring fellowships at North Carolina State are the Alcoa, ASEE-Leeds Northrup, Atomic Energy Commission, Celanese Corporation, Chemstrand, Douglas Aircraft Company, DuPont Company, E. Sig Johnson, Eastman Kodak Company, Edward Orton, Jr., Ceramic Foundation, Ford Foundation, General Electric, General Foods Corporation, Honor Society of Phi Kappa Phi, Kellogg, Mortex Chemical Products, North Carolina Grange (E. G. Moss Fellowship), National Aeronautics and Space Administration, National Science Foundation, National Institutes of Health, Office of Education of the Department of Health, Education and Welfare, R. J. Reynolds Tobacco Company, Rockefeller Foundation, Shell Oil Company, Sperry Gyroscope Company, Union Carbide Corporation, and Westinghouse.

Information relative to stipends, areas of research study supported by specific fellowships, and application forms may be obtained from the Graduate School or from the heads of the appropriate departments.

Assistantships

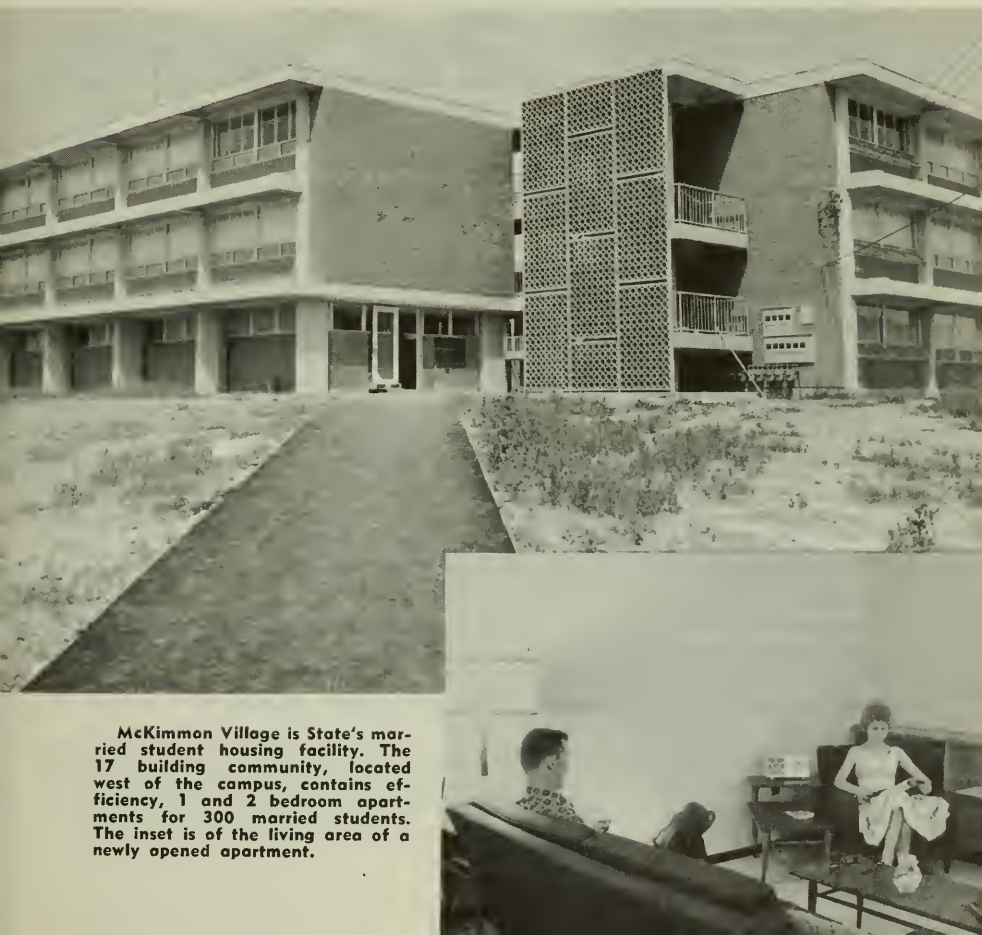
Graduate assistantships are granted to selected students who devote some part of their time to service duties for the University. Teaching assistantships carry stipends ranging from $2,400 to $2,700 for the academic year and permit the holder to enroll for sixty per cent of a full course load. The stipends for research assistantships range from $2,700 to $3,000 for a 12 months' appointment. The University offers 350 assistantships which require a service obligation in either teaching or research. Some of these are supported by funds

The new $1,000,000 General Laboratories Building provides laboratory and office space for the Departments of Physics and Statistics and major portions of the School of Physical Sciences and Applied Mathematics. The six story building is joined by a ramp to Harrelson Hall.

granted by the following agencies: the American Potash Institute, the Atomic Energy Commission, Best Foods, Campbell Soup Company, the Chilean Nitrate Education Bureau, Inc., Gerber Products Company, Hercules Powder Company, the Lilliston Implement Company, the Lilly Company, National Cotton Council, the North Carolina Agricultural Foundation, the North Carolina Dairy Foundation, the North Carolina Milk Commission, the Office of Naval Research, the Pacific Coast Borax Company, Peanut Growers Association, Pulp and Paper Foundation, Inc., the Ralston-Purina Company, R. J. Reynolds Tobacco Company, Shell Oil Company, the Tennessee Corporation, the Solvay Process Division of the Allied Chemical Company, Union Carbide Chemicals Company, and the Weyerhaeuser Foundation.

RESIDENCE FACILITIES

Dormitory facilities are provided on the campus for unmarried graduate students. The rental charge for double rooms is $85 per semester. A limited number of apartments are provided for married graduate students.



McKimmon Village is State's married student housing facility. The 17 building community, located west of the campus, contains efficiency, 1 and 2 bedroom apartments for 300 married students. The inset is of the living area of a newly opened apartment.

FIELDS OF INSTRUCTION

Departmental Announcements and Description of Courses*

DEPARTMENT OF AGRICULTURAL ECONOMICS

Graduate Faculty

Professors: Charles Edwin Bishop, *Head,* George L. Capel, Arthur James Coutu, Herman Brooks James, Richard Adams King, James Gray Maddox, Walter Henry Pierce, George Stanford Tolley, William Douglas Toussaint, James Claude Williamson, Jr.

Associate Professors: William Ray Henry, Dale Max Hoover, Paul R. Johnson, Charles Ray Pugh, James Arthur Seagraves, Richard Lee Simmons, Thomas Dudley Wallace

Assistant Professors: Loren Albert Ihnen, Edgar Walton Jones, Ernest Caleb Pasour, Jr., Ralph James Peeler

USDA Agricultural Economist: Joseph Gwyn Sutherland

The Department of Agricultural Economics offers programs of study leading to the Master of Agricultural Economics, the Master of Science and the Doctor of Philosophy degrees. Special emphasis is placed on the economics of agricultural production and marketing, analysis of programs and policies affecting agriculture and statistical techniques used in solving economic problems of the agricultural industry. The curriculum includes courses in advanced economic theory with special attention to agricultural problems including the use of econometric and linear programming techniques. Business management analysis, operations analysis and programming of firm and industry decisions are emphasized. Special attention is given to public policies influencing regional and national agricultural adjustments.

Collateral fields of study include statistics, rural sociology, history and political science, general economics,. agricultural education, and various technical departments in the School of Agriculture and Life Sciences.

As a part of their advanced training, students are required to prepare a thesis dealing with a recognized problem in agriculture. This part of the program affords an opportunity to learn how to apply theory and analytical techniques in the solution of agricultural problems.

The rapid growth and development of industry and agriculture in North Carolina and throughout the South have resulted in an increased demand for well-trained workers throughout the region. Opportunities for employment far exceed the number of qualified workers available to perform the many duties associated with the complex and technical problems of a developing economy. Many graduates of the Department of Agricultural Economics are employed in various agencies of the Federal and State government where they are engaged in research and educational work. Others are engaged in professional work with commercial organizations dealing in agricultural credit and the production and marketing of agricultural products.

* The course descriptions are planned for the academic years, 1964-65 and 1965-66, unless indicated otherwise. Specific courses may not be offered, however, if registration for the course or courses is too low or if faculty or facilities are not available. Courses in the 500 series are open to both seniors and graduate students. All courses in this series carry full graduate credit. Courses in the 600 series are open only to graduate students. Master's programs must include not less than 20 semester hours from courses in the 500 and 600 series.

The department is located on the second floor of Patterson Hall. It has a modern and well equipped departmental library, including all the major professional journals and United States Department of Agriculture publications. Experiment Station publications from other institutions throughout the United States are kept on file. Modern reproducing equipment is owned by the department, and used on many theses.

Computational facilities are ideal for students whose research problems involve extensive manipulation of data as well as for those students who want to learn to do their own programming. The department has a well trained clerical staff and owns one-half interest in an IBM 1620 computer. The University-wide computing center has an IBM 1410 at Raleigh and a Rand 1105 at Chapel Hill. Several analogue computers and a LINC-III computer are also located on the Raleigh campus.

Courses for Graduates and Advanced Undergraduates

AGC 512. Economic Analysis of Agricultural Factor Markets 0-3
Prerequisite: AGC 212 or Equivalent
An examination of the roles of land, labor and capital as factors of production in a modern agricultural economy, including major changes in the roles of these factors in recent years; analysis of changes in the supply and demand for the factors; a review of the structure and efficiency of markets for the factors, including relevance of the institutional and attitudinal setting in each type of market and an investigation of the nature of the demand-supply equilibration; a consideration of public policies relating to the use of the factors of production in agriculture in relation to theories of economic growth, with particular attention to land, credit, education and research programs affecting the factors of production used in agriculture in developing economies. Mr. Tolley.

AGC 521. Procurement, Processing and Distribution of Agricultural Products 3-0
Prerequisite: AGC 311 or Equivalent
A study of marketing firms as producers of marketing services and their role in the pricing process; the influence of government policies on their behavior of marketing firms; methods for increasing the efficiency of marketing agricultural products. Mr. Simmons.

AGC 523. Planning Farm and Area Adjustments 0-3
Prerequisite: AGC 303 or Equivalent
The application of economic principles in the solution of production problems on typical farms in the State; methods and techniques of economic analysis of the farm business; application of research findings to production decisions; development of area agricultural programs. Mr. Pasour.

AGC 533. Agricultural Policy 0-3
Prerequisite: AGC 212 or Equivalent
A review of the agricultural policy and action programs of the Federal Government in their economic and political setting; analysis of objectives, principal means, and observable results under short-term and long-term viewpoints, and under the criteria of resource use and income distribution within agriculture, and between agriculture and the rest of the economy; appraisal of alternative policy proposals; the effects of commodity support

programs on domestic and foreign consumption, and some of the international aspects of United States agricultural policy; the attempts at world market regulation, and the role of international organizations, agreements, and programs. Mr. Hoover.

AGC 551. Agricultural Production Economics **3-0**
Prerequisite: AGC 212 or Equivalent
An economic analysis of agricultural production, including production functions, cost functions, programming and decision-making principles; and the applications of these principles to farm and regional resource allocation, and to the distribution of income to and within agriculture.
Mr. Toussaint.

AGC 552. Consumption, Distribution, and Prices in Agriculture **0-3**
Prerequisite: AGC 212 or Equivalent
Basis for family decisions concerning consumption of goods and services and supply of productive factors; forces determining prices and incomes; interrelationships between economic decisions of the household and the firm.
Mr. West.

AGC 592. Topical Problems in Agricultural Economics **Maximum 6**
Prerequisite: Permission of Instructor
An examination of current problems in the field of agricultural economics with emphasis on the use of theory to define and facilitate the consideration of alternative solutions. Graduate Staff.

Courses for Graduates Only

AGC 602. Monetary and Fiscal Policies in Relation to Agriculture **0-3**
Prerequisite: AGC 551 or Equivalent
Aggregative theory needed to evaluate monetary and fiscal policies; fundamentals of model building; models involving income, employment, price levels, money supply, interest rates and other aggregative variables; relation of the models to the main economic magnitudes for the United States economy; institutional determinants of monetary and fiscal operations in the United States; stabilization, growth and equity objectives in relation to the structure of taxes and government revenue and current government policies; introduction to international monetary equilibrium and the relation of monetary-fiscal policies to agricultural incomes and prices.
Mr. Tolley.

AGC 611. Agricultural Economic Analysis **3-0**
Prerequisites: MA 112, AGC 551 or Equivalent
An economic analysis of agricultural products and inputs. Includes analysis of price-determining forces and factors influencing distribution of income within agriculture and between agriculture and the rest of the economy. Production, cost and demand functions are stressed, along with programming and decision-making principles and their application to decisions at the firm level and to regional resource allocation. Mr. Ihnen.

AGC 612. International Trade in Relation to Agriculture **0-3**
Prerequisites or Corequisites: AGC 602, AGC 641
The principles of international and interregional trade; structures of trade

relationships between countries engaged in the import or export of agricultural products; attempts at stabilizing trade and financial transactions.
Mr. Johnson.

AGC 631. Economic and Social Foundations of Agricultural Policy 3-0
Prerequisite: AGC 551 or Equivalent
The study of logical and empirical problems of inquiry into public policies and programs that affect agriculture; analysis of policy-making processes, interdependencies among economic, political and social objectives and action; the study of forces which shape economic institutions and goals and of the logic, beliefs and values on which policies and programs that affect agriculture are founded. Graduate Staff.

AGC 632. Welfare Effects of Agricultural Policies and Programs 0-3
Prerequisite: AGC 642
Description of the conditions defining optimal resource allocation; application of the conditions for maximum welfare in appraisal of economic policies and programs affecting resource allocation, income distribution, and economic development of agriculture. Mr. Bishop.

AGC 641. Economics of Production, Supply and Market Interdependency 0-3
Prerequisites or Corequisites: AGC 611, MA 211 or Equivalent
An advanced study in the logic of, and empirical inquiry into, producer behavior and choice among combinations of factors and kinds and quantities of output; aggregative consequences of individuals' and firms' decisions in terms of product supply and factor demand; factor markets and income distribution; general interdependency among economic variables.
Messrs. Seagraves, Toussaint.

AGC 642. Economics of Consumption, Demand and Market Interdependency 3-0
Prerequisites: AGC 641, ST 513 or Equivalent
An advanced study in the theory of, and research related to, household behavior; aggregative consequences of household decisions concerning factor supply and product demand; pricing and income distribution; economic equilibrium. Mr. Simmons.

AGC 651. (St 651) Econometric Methods I 3-0
Prerequisites: ST 421, ST 502, AGC 611 or Equivalent
The role and uses of statistical inference in agricultural economic research; measurement problems and their solutions arising from the statistical model and the nature of the data; limitations and interpretation of results of economic measurement from statistical techniques. Topics include the problems of specification, aggregation, identification, multicolinearity and autocorrelation. Attention also is given to expectations models and simultaneous stochastic equations. Mr. Wallace.

AGC 652. (See ST 652. Econometric Methods II.)

AGC 671. Analysis of Economic Development in Agriculture 3-0
Prerequisite: AGC 641
A theoretical and empirical study of the processes of economic growth; the problems of underdeveloped countries; the role of agriculture in a developing economy; an examination of policies and programs needed for effective economic development. Mr. Maddox.

AGC 699. Research in Agricultural Economics **Credits by Arrangement**
Prerequisites: Graduate Standing in Agricultural Economics, Consent of Graduate Advisory Committee
A consideration of research methods and procedures employed in the field of agricultural economics, including qualitative and quantitative analysis, inductive and deductive methods of research procedure, selection of projects, planning and execution of the research project.

Graduate Staff.

DEPARTMENT OF AGRICULTURAL EDUCATION
(See School of Education)

DEPARTMENT OF AGRICULTURAL ENGINEERING

Graduate Faculty

Professors: Francis Jefferson Hassler, *Head,* Henry Dittmus Bowen, William Eldon Splinter, Jan Van Schilfgaarde
Professor Emeritus: David S. Weaver
Associate Professor: Charles Wilson Suggs
Assistant Professors: James William Dickens, Barney Kuo-Yen Huang, William Hugh Johnson, Kenneth Allan Jordan, David Alan Link, Cliff R. Willey, Ralph E. Williamson

The Department of Agricultural Engineering offers programs of study for the Master of Science, Doctor of Philosophy and Master of Agricultural Engineering degrees. A bachelor's degree in Agricultural Engineering from an accredited curriculum or its equivalent entitles an individual to one of two approaches to graduate study. For those interested primarily in existing technologies, the Master of Agricultural Engineering program permits selections from a variety of advanced technical courses. Such study is appropriate to certain supervisory and managerial positions, technical sales, service and promotional work.

The Master of Science program takes into account the increasing rigor of modern engineering. Emphasis here is placed on mathematics and theory as the unifying link between otherwise widely divergent fields of knowledge, which are prerequisite to effective engineering advances in agricultural productions. As the student acquires competence in the advanced methods of science, he derives mathematical models for reduction of observational knowledge to engineering applications.

Study for the Doctor of Philosophy degree builds on the above Master of Science program by an additional year of formal study followed by a period of independent research to satisfy dissertation requirements.

Unusual opportunities are available for graduate student participation in departmental research programs. Current projects include: Animal Environment; Watershed Hydrology, Drainage and Irrigation; Crop Processing and Materials Handling; Field Production Operations; Fruit and Vegetable Mechanization; Pesticide Applications; Human Engineering; Engineering Economy. The systems approach to operations in crop and animal produc-

tions provides a variety of areas within which to define timely investigations.

Graduate students have access to a research shop which is manned by competent mechanics.

Information concerning fellowships and assistantships in Agricultural Engineering may be obtained from the head of the department.

Courses for Advanced Undergraduates

AGE 411. Farm Power and Machinery **3-3**
Prerequisite: AGE 211
This course is designed to provide students in Agricultural Engineering Technology with a knowledge of the operations of manufacturing and distributing organizations of farm machinery and their places in these organizations. Included is a practical course in farm tractors and engines with emphasis on familiarizing the student with component parts—their applications. Included is a practical course in farm tractors and engines with from the standpoint of power, performance and ratings.

AGE 433. Crop Preservation and Processing **3-0**
Prerequisite: AGE 341
This course defines the environmental requirements for preservation of crop quality as related to their physical and biochemical characteristics when harvested and during storage. The use of modern methods, equipment and engineering applications are exemplified in obtaining the required environments needed in solving present farm problem situations. Theory will also be phased into practical applications of the latest methods for farm processing of grains, seeds and feeds.

AGE 453. Bio-engineering Parameters **2-0**
Prerequisites: AGE 303, MA 301, AGE 352
Physical properties and response characteristics of plant materials are studied in their relationship to engineering analysis for production, harvesting and processing operations. Topics include germination, growth dynamics, physical properties for harvesting and materials handling, biological response criteria, environmental effects, theory of curing and drying and quality evaluation.

AGE 461. Analysis of Agricultural Production Systems **3-0**
Prerequisites: MA 201, EC 205, ST 361
This course is a survey of the basic methodology and techniques of operations research and system analysis, particularly as they apply to Agricultural Engineering. The costs and productivity of farm equipment, reliability theory, time study techniques, work efficiency, activity network problems, decision theory, game theory, model formulation, algorithm formulation, simulation, computational procedures, and case studies of operations research in agriculture are all discussed.

AGE 462. Functional Design of Field Machines **0-3**
Prerequisites: AGE 361, AGE 461, ME 301, SSC 200
A study of the modern farm tractor and the design of field machines from a functional point of view.

AGE 471. Soil and Water Conservation Engineering **0-3**
Prerequisites: SSC 200, CE 201, ST 361
A study is made of climate, runoff, infiltration, soil-water-plant relations and flow theory, as well as those processes that affect erosion. The above principles are applied to the study of engineering design practices in erosion control, drainage, irrigation and flood control.

AGE 481. Design of Farmstead Engineering Systems **0-3**
Prerequisites: AGE 453, AGE 461, AGE 491
Engineering principles will be combined with biological principles to develop a design procedure for non-field agricultural systems in which maximum profit can be obtained. The homeothermic mechanisms of animals will be used to indicate the influence of thermal environment upon animal growth and production. Techniques of labor efficiency and automation will be used in design. The technology of building design will be developed. Material selection and structural design for economic buildings will be indicated.

AGE 491. Electrotechnology for Agricultural Production **3-0**
Prerequisite: EE 332
A course in the application of electrical circuits, electronic circuits and electrostatics to problems in agricultural production systems. The practical aspects of motor selection, wiring and electronic circuitry will be given in the laboratory.

Courses for Graduates and Advanced Undergraduates

AGE 552. Instrumentation for Agricultural Research and Processing **2-0**
Prerequisites: MA 301, EE 331
Theory and application of primary sensors and tranducers. Utilization of electronic and solid state devices. Indicating, recording and control circuitry. Special circuitry for agricultural applications. Mr. Splinter.

AGE 590. Special Problems **Credits by Arrangement**
Prerequisite: Senior in Agricultural Engineering or Graduate Standing
Each student will select a subject on which he will do research and write a technical report on his results. He may choose a subject pertaining to his particular interest in any area of study in Agricultural Engineering.
Graduate Staff.

Courses for Graduates Only

AGE 654. Agricultural Process Engineering **3 or 3**
Prerequisite: MA 441
Generalized classical thermodynamics is extended by Onsager's relations to provide a theoretical basis for analyzing the energetics of systems that include life processes. Mr. Johnson.

AGE 661. Analysis of Function and Design of Farm Machinery **3 or 3**
Prerequisite: PY 411
Methods and tools used in determining the functional requirements of machine components; writing of machine specifications in terms of fundamental parameters; introduction of the principles of discriminate and indiscriminate mechanical selection of agricultural products with emphasis on the theory of servo-systems. Mr. Bowen.

AGE 671. Theory of Drainage, Irrigation and Erosion Control 0-4
Emphasis is placed on the physical and mathematical aspects of problems in conservation engineering and an attempt is made to rationalize procedures which have often come about through experience rather than through analytical considerations. Examples are presented of cases where such an analytical approach has already improved, or shows promise of improving, design criteria and procedures. (Offered in 1963-64 and alternate years.)
Mr. van Schilfgaarde.

AGE 681. Analysis of Function and Design of Farm Buildings 4 or 4
Prerequisite: AGE 481
A study of the functional requirements of farm structures with respect to man, animals and crops and development of the means of providing structures which fulfill the functional requirements. Application of the science and art of engineering in the solution of environmental problems. Advanced planning in the integration of structural environmental design.
Mr. Jordan.

AGE 695. Seminar 1-1
Prerequisite: Graduate Standing
Elaboration of the subject areas, techniques and methods peculiar to professional interest through presentations of personal and published works; opportunity for students to present and defend, critically, ideas, concepts and inferences. Discussions to point up analytical solutions and analogies between problems in Agricultural Engineering and other technologies, and to present the relationship of Agricultural Engineering to the socioeconomic enterprise. Mr. Hassler.

AGE 699. Research in Agricultural Engineering Credits by Arrangement
Prerequisite: Graduate standing in Agricultural Engineering
A maximum of six credits is allowed toward a Master's degree; no limitation on credits for Doctorate program.
Performance of a particular investigation of concern to Agricultural Engineering. The study will begin with the selection of a problem and culminate with the presentation of a thesis. Graduate Staff.

AGRICULTURE

AG 401. Principles and Methods of Extension Education 0-3
A study of the background, development, and operation of the Agricultural Extension Service. Consideration is given to major events leading to the establishment of Agricultural Extension, its objectives, organization, and philosophy. Major emphasis is placed upon the principles underlying Extension education together with methods of program building and teaching.

AG 503. The Programming Process in the Cooperative Extension Service and Related Organizations 0-3
Prerequisite: Bachelor's Degree
The principles and processes involved in programming, including basic theories and concepts supporting the program process. Attention will be given to the general framework in which programming is done, the organization needed, and the program roles of both professional and lay leaders.
Mr. Boone.

DEPARTMENT OF ANIMAL SCIENCE

Graduate Faculty

Professors: Ira Deward Porterfield, *Head,* Elliott Roy Barrick, Edward Guy Batte, George Hyatt, Jr., James Giacomo Lecce, James Edward Legates, Gennard Matrone, W. Ray Murley, Frank Houston Smith, Hamilton Arlo Stewart, Samuel B. Tove, Lester Curtis Ulberg, George Herman Wise

Associate Professors: Albert J. Clawson, Emmett Urcey Dillard, Lemuel Goode, Richard Douglas Mochrie, Harold Arch Ramsey, William Wesley Garry Smart, Jr., Milton B. Wise

Assistant Professors: Edward Vitangelo Caruolo, Donald Gould Davenport, James Murray Leatherwood, John Joseph McNeill, Allen Huff Rakes, Richard Monier Myers, Odis Wayne Robison

Advanced studies leading to the degrees of Master of Science and Doctor of Philosophy are offered in the Department of Animal Science. The graduate programs are presented in four subdivisions: Animal Breeding and Physiology, Animal and Dairy Husbandry, Animal Diseases, and Nutrition.

Students specializing in animal breeding concentrate their efforts in solving problems concerned with the efficient utilization of superior germ plasm. Further emphasis is provided in the areas of quantitative animal genetics and/or reproductive physiology. Herds and flocks of livestock, as well as small animals, are available near the campus. Environmental control chambers, surgery rooms, space for semen processing and storage are other off-campus facilities provided for studies in animal breeding.

Students specializing in animal and dairy husbandry may select options in nutrition, physiology and management with beef cattle, dairy cattle, sheep and swine. Animals of various types and breeds, which are available for research, are quartered on approximately 2,000 acres of land operated by the department. In addition, branch stations are located in all major geographic areas of North Carolina so that the research programs may be applied to the conditions existing throughout the State.

Students studying animal diseases are offered specialized work in pathology, parasitology, veterinary bacteriology and virology, and other phases of animal diseases. The Animal Disease Section is located in a modern animal disease laboratory building, which provides excellent facilities for research and teaching in the animal disease field. Included are large animal isolation units for work in the field of veterinary bacteriology and virology, parasitology, physiology, and bacteriology research laboratories and a diagnostic laboratory, and necropsy room.

Training offered to students in nutrition is focused on the fundamental aspects of the science of nutrition. In course programs the development of a strong foundation in the physical and the biological sciences is required. In research a wide choice of problems within current project areas, including microbial metabolism, energy metabolism, digestive mechanisms, and metabolism of micronutrients, lipids, proteins, and complex carbohydrates, are available. Animal and chemical laboratory facilities available and types of experiments conducted are such that graduate students in nutrition have the

opportunity to become familiar with principles and procedures employed in many different kinds of biological investigations ranging from micro studies of bacteria and of special components of animal cells to gross investigations of intact mammals.

All sections of the Department of Animal Science, with the exception of Animal Disease, are housed in Polk Hall. Modern research laboratories appropriate for the various areas of investigation are located in this building. A large-animal facility, located adjacent to the campus, serves as an intermediary between the farms and the laboratories. At this research center, phases of the physiology and nutrition programs are conducted.

The primary goal in all graduate programs in animal science is to provide the challenge and the opportunities for students to develop their ability to the degree that they can contribute creatively and continue to grow in their chosen profession.

Courses for Advanced Undergraduates

ANS 404. Dairy Farm Problems **0-3**
Prerequisite: ANS 201
Advanced study of practical dairy farm management including farm records, farm buildings, sanitation, roughage utilization and herd culling.

ANS 406. Animal Science Seminar **0-1**
Review and discussion of special topics and the current literature pertaining to all phases of Animal Production.

ANS 407. Advanced Livestock Production **0-4**
Prerequisites: GN 411, ANS 312
A study of the economic, nutritional, genetic, physiological and managerial factors affecting the operation of commercial and purebred livestock enterprises.

ANS 408. Reproduction and Lactation **0-3**
Prerequisite: ZO 301
Anatomy of the reproductive organs and mammary glands with detailed coverage of the physiological processes involved and of factors controlling and influencing them. A special research problem selected by the student is required.

Courses for Graduates and Advanced Undergraduates

ANS 503. (GN 503) Genetic Improvement of Livestock **3-0**
Prerequisite: GN 411 or Consent of Instructor
The application of genetic principles to the economic improvement of animal agriculture. Phenotypic and genetic relationships among economic traits as well as mode of inheritance and method of measurement of the traits. The role of inbreeding, outbreeding and selection methods in producing superior genetic populations. Mr. Robison.

ANS 505. Diseases of Farm Animals **3-0**
Prerequisites: CH 101, CH 103
The pathology of bacterial, viral, parasitic nutritional, thermal and mechanical diseases processes. Mr. Batte.

ANS 513. Needs and Utilization of Nutrients by Livestock **0-3**
Prerequisite: ANS 312 or Equivalent
Measurement of nutrients needs of livestock and the nutrient values of feeds. Nutritive requirements for productive functions. Mr. Wise.

ANS 590. Topical Problems in Animal Science **Maximum 6**
Special problems may be selected or assigned in various phases of Animal Science. Graduate Staff.

Courses for Graduates Only

ANS 602. (GN 602) Population Genetics in Animal Improvement **3-0**
Prerequisites: ST 512, GN 512
A study of the forces influencing gene frequencies, inbreeding and its effects, and alternative breeding plans. Mr. Legates.

ANS 604. (ZO 604) Experimental Animal Physiology **4-0**
Prerequisite: ZO 513 or Equivalent
A study of the theories and techniques involved in the use of animals in physiological investigation. Messrs. Ulberg, Wise.

ANS 614. (BO 614) Bacterial Metabolism **0-2**
Prerequisites: BO 514 or Equivalent; CH 551
The energy metabolism of bacteria; synthesis of carbohydrates, lipids, proteins, purines, pyrimidines, and nucleic acids; bacterial photosynthesis; enzyme formation and metabolic control mechanisms.
Mr. McNeill.

ANS 621. (CH 621) Enzymes and Intermediary Metabolism **4-0**
Prerequisites: CH 551 and Permission of Instructor
A study of the properties of enzymes and enzyme action; intermediary metabolism of carbohydrates, lipids, fatty acids, vitamins, and porphyrins; metabolic energy relationships. Mr. Tove.

ANS 622. (CH 622 and ST 622) Principles of Biological Assays **0-3**
Prerequisites: CH 551, ST 512
Techniques and designs of biological assays. The interrelationship of logical principles, designs, and analyses is emphasized.
Mr. Smart.

ANS 653. (CH 653) Mineral Metabolism **3-0**
Prerequisite: CH 551
Principles of mineral metabolism, with emphasis on metabolic functions, reaction mechanisms and interrelationships. Mr. Matrone.

ANS 690. Seminar in Animal Nutrition **1-1**
Prerequisite: Permission of Seminar Leaders
Orientation in philosophy of research, preparation for research and general research methodology. Graduate Staff.

ANS 699. Research in Animal Science **Credits by Arrangement**
A maximum of six hours is allowed toward the master's degree; no limitation on credits in doctorate programs. Graduate Staff.

BIOLOGICAL SCIENCES

BS 531. **(See ST 531, Biomathematics I.)**

BS 532. **(See ST 532, Biomathematics II.)**

DEPARTMENT OF BOTANY AND BACTERIOLOGY

Graduate Faculty

Professors: Glenn Ray Noggle, *Head,* Donald Benton Anderson, Earnest A. Ball, James Brainerd Evans, *Herbert Temple Scofield, Larry Alston Whitford

Visiting Professor: George John Schumacher

Professor Emeritus: Bertram Whittier Wells

Associate Professors: Ernest Oscar Beal, Arthur W. Cooper, Gerald H. Elkan, James W. Hardin, Jerome J. Perry, James Richard Troyer

Assistant Professors: Walter J. Dobrogosz, Joseph S. Kahn, Heinz Seltmann, Ralph E. Williamson

Members of the Microbiology Faculty

Professors: William Victor Bartholomew, John Lincoln Etchells, James Brainerd Evans, James Giacomo Lecce, Marvin Luther Speck

Associate Professor: Gerald H. Elkan

Assistant Professors: Frank B. Armstrong, Walter J. Dobrogosz, John Joseph McNeill

The Department of Botany and Bacteriology offers programs leading to the Master of Science and Doctor of Philosophy degrees in either Botany or Bacteriology. A wide range of areas of specialization is available within each of these programs.

Students majoring in Botany may select research problems in plant physiology, ecology, anatomy, morphology, phycology and systematic botany.

Students majoring in Bacteriology may select research problems in microbial physiology, metabolism or genetics, food microbiology or soil microbiology.

Adequate physical facilities and equipment are available for teaching and research in all phases of the department's program. Outstanding are the laboratory, growth chamber, and greenhouse facilities for research in bacteriology, morphology and anatomy, and physiology. The use of radioisotopes in physiological, phychological, and morphological research is supported by adequate facilities. A fine herbarium supports study in systematics and ecology. The availability in the State of a wide range of habitats with an accompanying diversity of flora provides opportunities for numerous research problems in ecology, phycology, and systematics.

Graduate students terminating their work at the master's level have a somewhat limited opportunity as professional botanists or bacteriologists. State, Federal and industrial employment is available as well as academic positions in some colleges and secondary schools. Holders of the Doctor of Philosophy degree will find opportunities for academic positions in colleges and universities, for research positions in Federal and State Experiment Stations, and for research and development work with private industrial or research institutions.

* On Leave

Courses for Advanced Undergraduates

BO 403. Systematic Botony **0-3**
Prerequisite: BO 103 or BS 100
A systematic survey of vascular plants emphasizing field identification, terminology, and general evolutionary relationships.

BO 412. General Bacteriology **4-0**
Prerequisites: CH 107 or CH 103, CH 221 or CH 220 Recommend But Not Required
An advanced biology course dealing with bacteria and other microorganisms, their structure, development, and function. Emphasis is placed on the fundamental concepts and techniques in microbiology such as isolation, cultivation, observation, morphology, and the physiology and nutrition of bacteria. The applications of microbiology, the role of microbes in nature, and their role in infection and immunity are considered.

BO 421. Plant Physiology **4-4**
Prerequisites: BO 103 or BS 100, 2 Courses in Chemistry
An introductory treatment of the chemical and physical processes occurring in higher green plants with emphasis upon the mechanisms, factors affecting, correlations between processes, and biological significance.

BO 441. Plant Ecology **-0**
Prerequisite: BO 103 or BS 100
An introduction to the study of plants in relation to their environment. Major topics considered are: factors of the environment; the structure, analysis, and dynamics of plant communities; past and present distribution of vegetation types.

Courses for Graduates and Advanced Undergraduates

BO 505. **(See FS 505. Food Microbiology.)**

BO 506. **(See FS 506. Advanced Food Microbiology.)**

BO 511. Advanced Bacteriology **0-3**
Prerequisite: BO 412
This course will present the principles and techniques of isolation and characterization of bacteria from a wide range of habitats. Particular stress will be given to the principles of enrichment techniques, differential and selective media, and pertinent diagnostic tests that are applicable to particular groups of bacteria. Messrs. Evans, Elkan.

BO 512. Morphology of Vascular Plants **3-0**
Prerequisite: BO 103 or BS 100
A study of comparative morphology, ontogeny and evolution of the vascular plants. Emphasis is placed upon the phylogeny of sexual reproduction and of the vascular systems. Mr. Ball.

BO 513. Plant Anatomy **0-3**
Prerequisite: BO 103 or BS 100
A study of the anatomy of the Angiosperms and Gymnosperms. The development of tissues is traced from their origin by meristems to their mature states. Mr. Ball.

BO 514. Introductory Bacterial Physiology **3-0**
Prerequisites: BO 412, CH 221 or 220; CH 551 (May Be Taken Concurrently.)
Emphasis will be placed on general principles and function with respect to the living cell. Included will be a study of cell structure, growth, death, reproduction, nutrition, and metabolism. An attempt will be made to illustrate the application of basic principles to applied areas of bacteriology and to other areas of basic science.
Messrs. Dobrogosz, Evans.

BO 521. Systematic Botany of Monocot Families **3-0**
Prerequisite: BO 403
A comprehensive survey of the systematics and evolution of monocot families. Special emphasis is given to terminology, morphology, identification and relationships. (Offered in 1965-66 and alternate years.)
Mr. Beal.

BO 523. Systematic Botany of Dicot Families **0-3**
Prerequisite: BO 403
A comprehensive survey of the systematics and evolution of dicot families. Special emphasis is given to terminology, morphology, identification, and relationships. (Offered in 1965-66 and alternate years.) Mr. Hardin.

BO 531. (See SSC 532. Soil Microbiology.)

BO 534. Physiology of Plant Cells **3-0**
Prerequisite: BO 421 or Equivalent; Advanced Preparation in Chemistry or Physics May Be Substituted With the Permission of the Instructor
An advanced treatment of basic plant processes at the cellular level with emphasis on theoretical principles. Mr. Troyer.

BO 535. Water, Solute and Gas Relations of Plants **0-2**
Prerequisite: BO 534
An advanced treatment of processes of higher plants involving exchange of materials between the plant and its surroundings and movement of materials within the plant. Theoretical principles are emphasized. (Offered in 1964-65 and alternate years.) Mr. Troyer.

BO 536. Growth and Development of Plants **0-2**
Prerequisite: BO 534
An advanced treatment of the physiology of growth and development of higher plants, with emphasis on theoretical principles. (Offered in 1965-66 and alternate years.) Mr. Troyer.

BO 544. Plant Geography **0-3**
Prerequisites: BO 403, 441, GN 411, or Equivalents
A course in descriptive and interpretive plant geography, synthesizing data from the fields of ecology, genetics, geography, paleobotany, and taxonomy. The course will include a survey of the present distribution of major vegetation types throughout the world, a discussion of the history and development of this present pattern of vegetation, and a discussion of the principles and theories of plant geography. (Offered in 1964-65 and alternate years.)
Mr. Cooper.

BO 545. Advanced Plant Ecology **0-3**
Prerequisites: BO 421, 441 or Equivalents
An advanced consideration, through class discussions and individual projects,

of the principles, theories and methods of plant ecology. (Offered in 1965-66 and alternate years.) Mr. Cooper.

BO 561. **(See GN 561. Biochemical and Microbial Genetics.)**

BO 570. Sanitary Microbiology **3-0**
Prerequisite: BO 412 or Consent of Instructor
Fundamental aspects of microbiology and biochemistry are presented and related to problems of stream pollution, refuse disposal and biological treatment. Laboratory exercises present basic microbiological techniques and illustrate from a chemical viewpoint some of the basic microbial aspects of waste disposal. Mr. Elkan.

BO 574. Phycology **0-3**
Prerequisite: BO 103 or Equivalent
An introduction to the structure, reproduction and importance of the classes of organisms which may be included in the algae. Considerable time is devoted to the local fresh-water and marine floras and the ecology of important species. Mr. Whitford.

Courses for Graduates Only

BO 614. **(See ANS 614. Bacterial Metabolism.)**

BO 620. Advanced Taxonomy **3-0**
Prerequisites: BO 521, 523 or Permission of Instructor
A course in the principles of plant taxonomy including the history of taxonomy, systems of classification, rules of nomenclature, taxonomic literature, taxonomic and biosystematic methods, and monographic techniques.
Mr. Hardin.

BO 635. The Mineral Nutritian af Plants **0-3**
Prerequisites: BO 521, 523 or Permission of Instructor
Discussion of diffusion, molecular specificity and energetics of active transport. The physical chemistry of the essential elements and its significance to their biochemical functions. Mr. Kahn.

BO 636. Discussions in Plant Physiology **0-1**
Prerequisite: BO 534
Group discussions at an advanced level of selected topics of current interest in plant physiology. Mr. Troyer.

BO 690. Bacteriology Seminar **1-1**
Scientific articles, progress reports in research, and special problems of interest to bacteriologists are reviewed and discussed. Graduate student credit allowed if one paper per semester is presented at seminar.
Graduate Staff.

BO 691. Botany Seminar **1-1**
Scientific articles, progress reports in research, and special problems of interest to botanists are reviewed and discussed. Graduate student credit is allowed if one paper per semester is presented at seminar.
Graduate Staff.

BO 692. Special Problems in Bacteriology **Credits by Arrangement**
Directed research in some specialized phase of bacteriology other than a thesis problem but designed to provide experience and training in research.
Graduate Staff.

BO 693. Special Problems in Botany **Credits by Arrangement**
Directed research in some specialized phase of botany other than a thesis problem but designed to provide experience and training in research.
Graduate Staff.

BO 699. Research **Credits by Arrangement**
Original research preparatory to writing a master's thesis or a Ph.D. dissertation.
Graduate Staff.

CERAMIC ENGINEERING
(See Department of Mineral Industries)

DEPARTMENT OF CHEMICAL ENGINEERING

Graduate Faculty

Professors: Edward Martin Schoenborn, *Head,* Richard Bright, James K. Ferrell, Kenneth Orion Beatty, Jr.
Associate Professors: David Boyd Marsland, Frances Marian Richardson, John Frank Seely
Assistant Professor: Edward Paul Stahel

The Department of Chemical Engineering offers programs of advanced study and research leading to the Master of Science and Doctor of Philosophy degrees. The Chemical Engineering faculty seeks to provide a close association between faculty and students, to promote a common interest in advanced professional study, and to encourage intensive investigation, and top-level creative activity.

Graduate work in Chemical Engineering is of increasing importance since it enables the student to attain a higher degree of specialized professional competence and at the same time to secure greater mastery of the sciences which underlie the quantitative aspects of chemical technology. The demand for chemical engineers with advanced training is greater now than at any time since the beginning of the chemical industry.

Students having had one or more years of training beyond the baccalaureate are especially needed for fundamental and applied research, for process development and design, for production, and even for management, technical services and sales. Private consulting work and careers in teaching usually demand a period of advanced study well beyond the normal four-year undergraduate program.

At present, major emphasis in the department is concerned with basic studies of unit operations such as fluid flow, heat transfer at high and low temperatures, distillation, solvent extraction, etc., with thermodynamics, reaction kinetics, phase equalibria, plastics technology, process measurement and control, and many other aspects of chemical technology. The varied interests of an exceptionally well-qualified staff can provide guidance for advanced study in any phase of chemical engineering. Strong supporting programs of work are also available in mathematics, statistics, physics, chemistry, nuclear engineering, metallurgy, the life sciences, textiles, and other fields of engineering.

The Department of Chemical Engineering occupies the four-story east wing of the Riddick Engineering Laboratories building. Modern, well-equipped laboratories are provided with all necessary services for both teaching and research. A wide variety of special facilities such as X-ray equipment, spectrophotometers, electron microscope, electro-mechanical testing machine, electronic controllers and recorders, etc., are available for graduate research.

In cooperation with the Department of Engineering Research, members of the Chemical Engineering staff conduct a number of important research projects which are supported by industry, and by State and governmental agencies. Graduate students assisting on these projects not only acquire financial assistance but gain valuable research experience on problems of current interest.

In addition to research assistantships, the department also offers each year a limited number of graduate assistantships for part-time work in the department. These may be for teaching, laboratory preparation, etc., or for research, as the needs arise. Appointments are for one academic year of nine months for half-time work and at the present carry a stipend of $2,400. They are renewable upon evidence of satisfactory performance.

Courses for Advanced Undergraduates

CHE 421, CHE 422. Reactor Energy Transfer **3-3**
Prerequisites: MA 202, PY 208
Thermodynamics, heat transfer and fluid flow with emphasis on the problems and methods used in the design and analysis of nuclear reactors.

CHE 425. Process Measurement and Control **0-3**
Prerequisite: CHE 312
Required of Seniors in Chemical Engineering
Theory and application of methods for measuring, recording, transmitting and controlling process variables. The techniques of analysis, beginning with process elements in automatic control and proceeding through system analysis, are employed. Commercial instruments are available for simulating industrial control problems.

CHE 427, CHE 428. Separation Processes I, II **3-3**
Prerequisite: CHE 311
Required of Seniors in Chemical Engineering
A study of the principles underlying such unit operations as absorption, extraction, distillation, drying, filtration, etc., with emphasis on procedures and economic considerations.

CHE 431. Chemical Engineering Laboratory I **0-2**
Prerequisite: CHE 311
Required of Juniors in Chemical Engineering
Laboratory work on typical apparatus involving unit operations. Experiments are designed to augment the theory and data of lecture courses and to develop proficiency in the writing of technical reports.

CHE 432, CHE 433. Chemical Engineering Laboratory II, III **2-2**
Prerequisites: CHE 312, CHE 431
Required of Seniors in Chemical Engineering
A continuation of CHE 431.

CHE 446. Chemical Process Kinetics **3-0**
Prerequisite: CHE 315
Required of Seniors in Chemical Engineering
A basic study of homogeneous and heterogeneous chemical reactions, and of catalysis.

CHE 460. Seminar **1-1**
One Semester Required of Seniors in Chemical Engineering
Professional aspects of chemical engineering; topics of current interest in chemical engineering.

CHE 470. Chemical Engineering Projects **2-2**
(By Arrangement)
Elective for Seniors in Chemical Engineering
Introduction to research through experimental, theoretical and literature studies of chemical engineering problems. Oral and written presentation of reports.

Courses for Graduates and Advanced Undergraduates

CHE 511. Problem Analysis for Chemical Engineers **3 or 3**
Prerequisite: CHE 428, MA 301
The application of the methods of mathematical analysis to the formulation and solution of problems in transport phenomena, transient phenomena in unit operations, process dynamics, and thermodynamics. Study and use of analog computer solutions of these problems.
Mr. Ferrell.

CHE 513. Thermodynamics I **3 or 3**
Prerequisite: CHE 315 or Equivalent
An intermediate course in thermodynamic principles and their application to chemical and phase equilibria. The course is largely from a macroscopic viewpoint but consideration will be given to some aspects of the statistical viewpoint.
Mr. Beatty.

CHE 515. Transport Phenomena **3 or 3**
Prerequisite: CHE 312
A theoretical study of transport of momentum, energy, and matter with emphasis on the latter two. The diffusional operations, including coupled heat and mass transfer, are introduced in the light of the theory.
Mr. Marsland.

CHE 517. Kinetics and Catalysis **3 or 3**
Prerequisite: CHE 446
An intensive study of homogeneous and heterogeneous kinetic reactions. Emphasis will be placed on fundamental approaches, experimental methods, and mathematical techniques in engineering analysis of chemical reaction systems.
Mr. Stahel.

CHE 540. Electrochemical Engineering **3 or 3**
Prerequisite: Physical Chemistry
The application of electrochemical principles to such topics as electrolysis, electroanalysis, electroplating, metal refining, etc.
Mr. Schoenborn.

CHE 541. Cellulose Industries **3 or 3**
Prerequisite: Organic Chemistry
Methods of manufacture and application of cellulose chemical conversion products. Emphasis placed on recent developments in the field of synthetic fibers, films, lacquers, and other cellulose compounds.
Mr. Seely.

CHE 543. Technology of Plastics **3 or 3**
Prerequisite: Organic Chemistry
The properties, methods of manufacture, and applications of synthetic resins. Recent developments in the field are stressed.
Mr. Seely.

CHE 551. Thermal Problems in Nuclear Engineering **3 or 3**
Prerequisites: ME 302 or ME 303; or CHE 311; or Equivalent
The design and operation of nuclear reactors and the utilization of the power from them involves major problems in nearly every phase of heat transfer, and many important problems in fluid flow. Possible solutions to these problems are severely affected by the influences of radiation on heat transfer media, hazards of handling radioactive substances, etc. The course considers the thermal problems of nuclear reactor design and the principles of fluid flow and heat transfer necessary to their solutions. The course is intended for engineers and science students with backgrounds in physics and mathematics and elementary thermodynamics. Mr. Beatty.

CHE 597. Chemical Engineering Projects **1 to 3 Credits**
Prerequisite or Concurrent: CHE 412
A laboratory study of some phase of chemical engineering or allied field.
Graduate Staff.

Courses for Graduates Only

CHE 610. Heat Transfer **3 or 3**
Prerequisite: CHE 515
An advanced course dealing primarily with heat transfer between liquids and solids, optimum operating conditions and design of equipment, conduction, heating and cooling of solids, radiant heat transmission.
Mr. Beatty.

CHE 621. Mass-Transfer Operations **3 or 3**
Prerequisite: CHE 515
An application of transport theory and empirical devices to the analysis, synthesis and design of mass-transfer equipment. The operations of absorption, extraction, distillation, humidification, drying, etc., will be considered.
Mr. Marsland.

CHE 622. Chemical Reaction Engineering **3 or 3**
Prerequisite: CHE 517
An advanced study of ideal and real reactor systems. The approach employed is twofold: 1. Characterization of actual systems by empirical rate expressions coupled with fundamental analysis; 2. Simulation of coupled physical and chemical processes in a reactor by solution of various types of physical models. Mr. Stahel.

CHE 623. Fluid and Particle Dynamics **3 or 3**
Prerequisite: CHE 515
The principles of fluid dynamics and their application to laminar and turbulent flow, flow in closed channels, flow in packed beds and porous media, particle technology, industrial rheology, and two-phase flow.
Mr. Ferrell.

CHE 624. Process Dynamics **3 or 3**
Prerequisite: CHE 511
A detailed study of the dynamic response of typical chemical process equipment including instrumentation and process control devices. Fundamental concepts of automatic control of process variables such as temperature, pressure flow, liquid level, etc. Mr. Ferrell.

CHE 625. Thermodynamics II **3 or 3**
Prerequisite: CHE 513
A consideration of various thermodynamic topics of special interest to chemical engineers. The effects of high pressures and high temperatures on equilibria, relationship of thermodynamics to rate process, thermodynamics of the steady state including coupled transfer process, and experimental methods in thermodynamics would be typical.
Mr. Beatty.

CHE 631. Chemical Process Design **3 or 3**
Prerequisite: CHE 428
Design and selection of process equipment, through solution of comprehensive problems involving unit operations, kinetics, thermodynamics, strength of materials and chemistry.
Graduate Staff.

CHE 690. Readings in Chemical Engineering **Credits by Arrangement**
A comprehensive survey of the literature in a specified area, and an exhaustive survey on a chosen topic within that area, under the direct guidance of the thesis adviser. This course has the goals of (a) mature selection of a research topic, and (b) preparation for a research proposal in fullest possible detail.
Graduate Staff.

CHE 693. Advanced Topics in Chemical Engineering **1 to 3 Credits (Per Semester)**
A study of recent development in chemical engineering theory and practice, such as ion exchange, crystallization, mixing, molecular distillation, hydrogenation, fluorination, etc. The topic will vary from term to term.
Graduate Staff.

CHE 695. Seminar **1-1**
Literature investigations and reports of special topics in chemical engineering and allied fields.
Graduate Staff.

CHE 699. Research **Credits by Arrangement**
Independent investigation of an advanced chemical engineering problem. A report of such an investigation is required as a graduate thesis.
Graduate Staff.

DEPARTMENT OF CHEMISTRY

Graduate Faculty

Professors: Ralph Clay Swann, *Head,* David Marshall Cates*, George Osmore Doak, Richard Henry Loeppert, Gennard Matrone*, Walter John Peterson, Willis Alton Reid, Cowin Cook Robinson, Henry Ames Rutherford*, Alfred J. Stamm*, Paul Porter Sutton, Samuel B. Tove*, Joseph Arthur Weybrew*

Adjunct Professor: Monroe Eliot Wall

Associate Professors: Carl Lee Bumgardner, Alonzo Freeman Coots, Leon David Freedman, Forrest William Getzen, Louis Allman Jones, Richard Coleman Pinkerton, Raymond Cyrus White

Assistant Professors: Lawrence Hoffman Bowen, George Gilbert Long, Edward Carroll Sisler, William Preston Tucker

The Department of Chemistry offers the degree of Master of Science in Chemistry. Instruction is available in all major areas of chemistry.

Before the master's program is initiated, a student must have met the requirements set forth by the Committee on Professional Training of the American Chemical Society for the baccalaureate degree, either at the institution in which he received his undergraduate training or at North Carolina State. The minimum course requirements in chemistry for the bachelor's degree consist of four basic year courses in general, analytical, physical, and organic chemistry, plus one semester of inorganic chemistry and at least two advanced courses. The equivalent of two years of college mathematics, including at least one year of differential and integral calculus and one semester of differential equations, is required.

Graduates are eligible for positions in industry, educational institutions or in research laboratories. Many graduates with the Master of Science degree have continued their education toward the Doctor of Philosophy degree with a major in one of the branches of chemistry.

The Department of Chemistry is equipped with standard instruments and apparatus for both teaching and research. Many items of specialized equipment are available. Such equipment includes Geiger counters, a gamma spectrometer, proportional counters, a neutron source, a double grating infrared spectrometer, an ultraviolet-visible-near infrared absorption spectrophotometer, a grating emission spectrograph, a photofluorimeter, a coulometer, controlled potential electrodeposition apparatus, polarographs, conductivity bridges, oscillometers, high pressure reactors, a precision refractometer, polarimeters, fractionating columns, controlled atmosphere boxes, etc.

A shop equipped with standard power tools (drill press, lathes, band saws, etc.) is available to research workers for construction of special apparatus. Glass-blowing facilities are also available.

Areas of research specialization include kinetics of gas phase reactions; problems in electrochemistry; distribution and structure of the flavin enzymes; charged-particle cross-section measurements; application of radiotracer techniques to physical chemistry problems; research in fission product

* Affiliated Graduate Faculty member.

analysis, neutron activation and nuclear thermodynamics; synthesis and properties of organophosphorus and organoarsenic compounds; structure of organometallic compounds; kinetics of inorganic reactions; relation of chemical structure to herbicidal properties; problems in infrared and ultraviolet spectroscopy; problems in solid state chemistry; mechanisms involved in plant physiological processes; techniques of spectrographic analysis and their application in research with plants, soils, and animals.

Courses for Advanced Undergraduates

CH 411. Analytical Chemistry I **4-4**
Prerequisites: CH 431, CH 432
Corequisites: CH 433, CH 434
An introduction to analytical chemistry, including both classical and modern techniques involving the distribution of a component between phases. Gravimetric methods, gas chromatography and adsorption techniques are included.

CH 413. Analytical Chemistry II **4-0**
Prerequisite: CH 411
A continuation of Analytical Chemistry I with emphasis upon modern approaches to acid-base chemistry, oxidation-reduction, potentiometric methods, and spectrophotometry.

CH 420. Organic Preparations **0-3**
Prerequisites: Three Years Chemistry Including CH 223
Experiments selected to acquaint the student with advanced methods and techniques in the preparation of organic substances.

CH 431. Physical Chemistry I **3-3**
Prerequisites: CH 107, MA 202, PY 207
On intensive study of the states of matter, solutions, colloids, homogeneous and heterogeneous equilibrium, reaction kinetics, electrolysis, conductance, oxidation reactions, and ionic equilibrium.

CH 432. Physical Chemistry Laboratory **1-0**
Corequisite: CH 431
Laboratory courses to accompany lecture work in Physical Chemistry I.

CH 433. Physical Chemistry II **3-3**
Prerequisite: CH 431
A continuation of CH 431.

CH 434. Physical Chemistry Laboratory **0-1**
Corequisite: CH 433
Laboratory course to accompany lecture work in Physical Chemistry II.

CH 435. Physical Chemistry III **3-0**
Prerequisite: CH 433
An intensive study of the structure of atoms and molecules, an introduction to statistics, and selected topics in modern physical chemistry.

CH 441. Colloid Chemistry **0-3**
Prerequisites: CH 220, CH 215
Adsorption, preparation, properties, constitution, stability and application of sols, gels, emulsions, foams, and aerosols; dialysis; Donnan membrane equilibrium.

CH 491. Reading in Honors Chemistry **Credits by Arrangement**
A reading course for exceptionally able students at the senior level. The students will do extensive reading in areas of advanced chemistry and will present written reports of their findings.

Courses for Graduates and Advanced Undergraduates

CH 501. Inorganic Chemistry I **3-0**
Prerequisite: CH 433
Modern inorganic chemistry from the point of view of the chemical bond. Topics covered include chemical periodicity and its origins in atomic structure; the ionic bond and electronegativity; crystal structure and bonding in ionic solids; the metallic state, conduction and semiconductors; the preparation and properties of illustrative compounds. Mr. Pinkerton.

CH 503. Inorganic Chemistry II **0-3**
Prerequisite: CH 501
A continuation of CH 501. Topics covered include the hydrogen molecule-ion and the theory of the covalent bond; molecular orbitals and hybridization; dipole moments and magnetic properties; the theory of acids and bases; nonaqueous solvents; co-ordination compounds, carbonyls and quasi-aromatic compounds; and the chemistry of the transition metals, lanthanides and actinides. Mr. Long.

CH 511. Chemical Spectroscopy **3-0**
Prerequisite: CH 433
Theory, analytical applications and interpretation of spectra as applied to chemical problems. Major emphasis will be placed upon ultraviolet, visible and infrared spectra. Mr. Long.

CH 512. (TC 512) Chemistry of High Polymers **0-3**
Prerequisite: CH 431
Principles of condensation and free radical polymerization; kinetics and molecular weight distribution; copolymerization and composition; emulsion polymerization; structure. Mr. Cates.

CH 513. Electroanolyticol Chemistry **0-3**
Prerequisite: CH 413
A course in electroanalytical chemistry including the foundations of theoretical electrochemistry. Topics covered include potentiometric measurements and electrical resistance; diffusion and transport; theory of dilute solutions; polarography and amperometric measurements; surface effects and electrode kinetics; electrochemistry in non-aqueous systems.
Mr. Pinkerton.

CH 521. Advanced Organic Chemistry I **3-0**
Prerequisites: Three Years Chemistry Including CH 223
Resonance; reaction mechanisms; hydrocarbons, organic halides, alcohols, amines, and carbonyl compounds. Mr. Doak.

CH 523. Advanced Organic Chemistry II **0-3**
Prerequisite: CH 521
Stereochemistry of organic compounds, including steroids and other natural products. Mr. Doak.

CH 525. Physical Organic Chemistry **0-3**
Prerequisites: CH 223, CH 433
Theoretical and physical aspects of organic chemistry; structure and mechanism in organic chemistry. Mr. Loeppert.

CH 527. Chemistry of Metal-Organic Compounds **3-0**
Prerequisites: Three Years Chemistry Including CH 223
A study of the preparation, properties and reactions of compounds containing the carbon-metal bond, with a brief description of their uses.
Mr. Doak.

CH 528. Qualitative Organic Analysis **4-0**
Prerequisites: Three Years Chemistry Including CH 223
A study of functional groups; separation and identification of compounds; preparation of derivatives. Mr. Doak.

CH 531. Chemical Thermodynamics **3-0**
Prerequisites: CH 433, MA 301
An extension of elementary principles to the treatment of ideal and real gases, ideal solutions, electrolytic solutions, galvanic cells, surface systems, and irreversible processes. An introduction to statistical thermodynamics and the estimation of thermodynamic functions from spectroscopic data. (Offered in alternate years.) Mr. Sutton.

CH 533. Chemical Kinetics **0-3**
Prerequisites: CH 433, MA 301
An intensive survey of the basic principles of chemical kinetics with emphasis on experimental and mathematical techniques, elements of the kinetic theory, and theory of the transition state. Applications to gas reactions, reactions in solution, and mechanism studies. (Offered in alternate years.)
Mr. Bowen.

CH 535. Surface Phenomena **3-0**
Prerequisites: CH 433, MA 301
An intensive survey of the topics of current interest in surface phenomena. This course is designed to cover the foundations of the present understanding of surface behavior. Formulation of basic theories are presented together with illustrations of their current applications. (Offered in alternate years.)
Mr. Getzen.

CH 537. Quantum Chemistry **0-3**
Prerequisites: CH 435, PY 401, PY 407
The elements of wave mechanics applied to stationary energy states and time-dependent phenomena. Applications of quantum theory to chemistry, particularly chemical bonds. (Offered in alternate years.)
Mr. Coots.

CH 543. Radioisotope Principles **3-0**
Prerequisites: CH 433, PY 207, MA 202
A presentation of the basic knowledge of radioactivity, nuclear reactions, ionizing radiations, and radiochemistry essential to competence in the use of radioisotopes. Mr. Coots.

CH 544. Radioisotope Techniques **1-0**
Corequisite: CH 543
A laboratory course in the physical and chemical techniques essential to competence in the use of radioisotopes. Mr. Coots.

CH 545. Radiochemistry **0-3**
Prerequisites: CH 543 or PY 407, PY 410
An advanced presentation of the applications of radioactivity to chemistry and of the applications of chemistry to the radioactive elements, particularly the heavy elements and fission products. Mr. Coots.

CH 546. Radiochemistry Laboratory **0-1**
Corequisite: CH 545
The laboratory work associated with CH 545 Radiochemistry.
Mr. Coots.

CH 551. General Biological Chemistry **3-3**
Prerequisites: Three Years Chemistry Including CH 223
The chemical constitution of living matter. Biochemical processes as well as compounds are studied. Mr. Peterson.

CH 552. General Biological Chemistry Laboratory **2-2**
Corequisite: CH 551
Laboratory course to accompany lecture work in General Biological Chemistry . Graduate Staff.

CH 553. Chemistry of Proteins and Nucleic Acids **0-3**
Prerequisite: CH 551
Composition, distribution, structure, properties and metabolism of amino acids, proteins, and nucleic acids. Graduate Staff.

CH 555. Plant Chemistry **0-3**
Prerequisite: CH 551
Composition of plants; properties, nature, and classification of plant constituents; changes occurring during growth, ripening and storage of plant products. Mr. Sisler.

CH 561. (TC 561) Chemistry of Fibers **3-0**
Prerequisite: CH 223
The theory of fiber structure; the relationship between chemical structure and physical properties of natural and man-made fibers; the nature of the chemical reactions which produce degradation of fibers; the production of man-made fibers. Mr. Rutherford.

Courses for Graduates Only

CH 621. (ANS 621) Enzymes and Intermediary Metabolism **4-0**
Prerequisite: CH 551
A study of the properties of enzymes and enzyme action; intermediary metabolism of carbohydrates, amino acids, fatty acids, vitamins, purines and porphyrins; metabolic energy relationships. Mr. Tove.

CH 653. (ANS 653) Mineral Metabolism **3-0**
Prerequisite: CH 551
Principles of mineral metabolism, with emphasis on metabolic functions, reaction mechanisms, and interrelationships. Mr. Matrone.

CH 671. Advanced Physical Chemistry **3-0**
Prerequisite: CH 533
A thorough review of the fundamental principles of physical chemistry with extension and application of these to the study of solid state.
Mr. Sutton.

CH 672. Advanced Physical Chemistry **0-3**
Prerequisite: CH 671
The elements of statistical mechanics and kinetic theory, in terms of which certain topics from CH 671 will be more exhaustively developed.
Mr. Sutton.

CH 691. Seminar **1-1**
Prerequisite: Graduate Standing in Chemistry
Required of graduate students with a major in Chemistry.
Scientific articles, progress reports in research, and special problems of interest to chemists are reviewed and discussed. A maximum of two semester credits is allowed toward the master's degree, but any number toward the doctorate. Graduate Staff.

CH 695. Special Topics in Chemistry **Maximum 3 Credits**
Prerequisites: Forty Semester Credits in Chemistry
Critical study of some special problems in one of the branches of Chemistry.
Graduate Staff.

CH 699. Chemical Research **Credits by Arrangement**
Prerequisites: Forty Semester Credits in Chemistry
Special problems that will furnish material for a thesis. A maximum of six semester credits is allowed toward a master's degree; there is no limitation on credits in doctorate programs. Graduate Staff.

DEPARTMENT OF CIVIL ENGINEERING

Graduate Faculty

Professors: Charles Raymond Bramer, *Acting Head,* Ralph Eigil Fadum, Charles Russell McCullough, Carroll Lamb Mann, Jr., Charles Smallwood, Jr., *Graduate Administrator,* Mehemet Ensar Uyanik
Associate Professors: Richard Hugh Bigelow, Paul Day Cribbins, John William Horn, Harvey Edward Wahls, Paul Zung Teh Zia
Assistant Professors: Michael Amein, John Frederick Ely, Charles Page Fisher, Donald McDonald
Visiting Lecturer: Abdel-Aziz Ismail Kashef

The Department of Civil Engineering offers programs of study leading to Master of Science and Doctor of Philosophy degrees. Graduate course work is available in the fields of sanitary engineering, soil mechanics and foundation engineering, structural engineering, and transportation engineering. Whereas the Master of Science program would normally include course work in only one of these specialty fields, a program of study leading to the Doctor of Philosophy degree would encompass course work in a related combination of these fields.

Laboratory facilities for sanitary engineering research work include an hydraulics laboratory, a chemical laboratory, and a biological laboratory.

For work in soil mechanics and foundation engineering, a fully-equipped laboratory with modern soil-testing equipment is available.

Facilities for structural engineering research include a well-equipped physical testing laboratory, an air-controlled structural models laboratory, and a special laboratory for testing large models or full-scale structures.

Transportation engineering facilities are a bituminous laboratory, an airphoto interpretation laboratory, a photogrammetry laboratory, and a traffic engineering laboratory provided with traffic control devices.

In addition to these facilities, equipment for research is made available by the Department of Engineering Research.

Some unique opportunities for research are offered the graduate students in Civil Engineering by reason of the location of North Carolina State in the State's Capital City. There are a number of cooperative research endeavors with municipal and State governmental agencies that provide funds for research assistantships.

The resources of the institution also provide unique opportunities for combining studies in Civil Engineering with studies in other related fields.

The broad nature of water resources problems has been recognized by the creation of a "Water Resources Institute" under the joint direction of the Deans of the Graduate School, the School of Engineering and the School of Agriculture and Life Sciences. Students in the major disciplines are urged to select one of the many aspects of the control, conservation and management of this resource as a topic for study and research.

In recognition of the need by industry for personnel with training in water supply and the abatement of water pollution, the Civil Engineering Department suggests that students in the many curricula leading to positions in industry (food processing, textile chemistry, pulp and paper technology, chemical engineering, zoology and others) consider courses of instruction in sanitary engineering for minor sequences for advanced degrees. Among the courses appropriate for such students are the following: CE 484, Water Resources Engineering II; CE 571, Theory of Water and Sewage Treatment; CE 573, Analysis of Water and Sewage; CE 673, Industrial Water Supply and Waste Disposal; and CE 674, Stream Sanitation.

There exists a growing need for the coordination of transportation facilities and land planning and for individuals with competence in both fields. To fulfill this need, an advanced program leading to a post-baccalaureate degree in engineering, majoring in transportation engineering, and to the degree of Master of Regional Engineering is offered through the combined resources of the Department of Civil Engineering at North Carolina State and the Department of City and Regional Planning at the University of North Carolina at Chapel Hill. Qualified students have the opportunity to schedule their courses in instruction to enable them to qualify for both advanced degrees.

The program is designed for students who are desirous of becoming technically proficient in both the fields of transportation engineering and city and regional planning. The minimum residence requirements include two academic years plus a summer internship. The curriculum includes the major core courses for both the advanced transportation engineering program and the city and regional planning program, plus supplementary courses important to both endeavors and a thesis. A bachelor's degree in engineering, including a knowledge of transportation engineering, from an institution of recognized standing is required for admission to the program. Applicants who do not meet these requirements in full may submit their credentials for examination and consideration.

Further information concerning the joint program may be obtained from the Department of Civil Engineering at North Carolina State in Raleigh or from the Department of City and Regional Planning at the University of North Carolina in Chapel Hill.

Courses for Advanced Undergraduates

CE 405, CE 406. Transportation Engineering I, II **4-4**
Prerequisites: CE 201, CE 331, CE 342
Required of Seniors in Civil Engineering
An integrated approach to the planning, design and operation of transportation systems. Engineering and economic aspects of the basic transport modes, including highway, rail, water and air facilities, are investigated from the viewpoint of the civil engineer.

CE 421. Structural Design I **3-0**
Prerequisites: CE 324, EM 301
Required of Seniors in Civil Engineering and Civil Engineering Construction Option
Basic design concepts. Analysis and design of tension, compression and flexural members in metal. Behavior and design of connections—riveted, bolted and welded. Term project in design of mill-building bent.

CE 422. Structural Design II **0-3**
Prerequisites: CE 421, CE 425
Required of Seniors in Civil Engineering
Analysis and design, in reinforced concrete, of beams in flexure, diagonal tension, bond and anchorage; axially loaded columns, eccentrically loaded columns, footings, retaining walls, continuous beams and one-way slabs. Introduction to ultimate strength design. Term project in design of a multi-story building frame in reinforced concrete.

CE 425. Structural Analysis II **3-0**
Prerequisites: CE 324, EM 301
Required of Seniors in Civil Engineering
Deflection of beams and trusses; indeterminate stress analysis by moment area, slope deflection and moment distribution.

CE 429. Structural Design III **0-3**
Prerequisite: CE 421
Required of Seniors in Civil Engineering Construction Option
Analysis and design of reinforced concrete beams, columns, footings and retaining walls. Design of timber beams, columns and connections. Term project in planning and making structural design for the timber forming needed for a reinforced concrete building.

CE 443. Foundations **0-3**
Prerequisite: CE 421
Required of Seniors in Civil Engineering Construction Option
Identification and classification of soils; geological aspects of foundation engineering; methods of investigating subsoil conditions; control of water; types of foundations and conditions favoring their use; legal aspects of foundation engineering.

CE 461. Project Planning and Control I **3-0**
Prerequisite: CE 362
Required of Seniors in Civil Engineering Construction Option
Analysis of construction plant layout requirements and performance characteristics of equipment.

CE 462. Project Planning and Control II **0-3**
Prerequisite: CE 461
Required of Seniors in Civil Engineering Construction Option
Scheduling, analysis and control of construction projects.

CE 464. Legal Aspects of Contracting **0-3**
Prerequisite: Senior Standing
Required of Seniors in Civil Engineering Construction Option; elective
Legal aspects of construction contract documents and specifications; owner-engineer-contractor relationships and responsibilities; bids and contract performance; labor laws.

CE 483. Water Resources Engineering I **3-0**
Prerequisite: CE 382
Required of Seniors in Civil Engineering
The hydrological cycle is studied with particular emphasis on those phases that are of engineering significance. The occurrence and distribution of water; rainfall, runoff, ground water. The development and control of water resources.

CE 484. Water Resources Engineering II **0-3**
Prerequisite: CE 483
Required of Seniors in Civil Engineering
A synthesis of mechanics, chemistry and hydrology in the design of elements of water resources systems. Water supply, treatment and distribution. Waste water collection, treatment and disposal. Consideration of flood control and stream flow regulation.

CE 485. Elements of Hydraulics and Hydrology **3-0**
Prerequisite: EM 303
Required of Seniors in Civil Engineering Construction Option
Elements of fluid mechanics, hydraulics and hydrology, with application to problems in construction engineering.

Courses for Graduates and Advanced Undergraduates

CE 507. Airphoto Analysis I **3-0**
Prerequisite: Junior Standing
Engineering evaluation of aerial photographs, including analysis of soils and surface drainage characteristics. Mr. McCullough.

CE 508. Airphoto Analysis II **0-3**
Prerequisite: CE 507
Engineering evaluation of aerial photographs, including analysis of soils projects. Mr. McCullough.

CE 514. Municipal Engineering Projects **0-3**
Prerequisite: Senior Standing
Special problems relating to public works, public utilities, urban planning and city engineering. Messrs. Horn, Smallwood.

CE 515. Transportation Operations **3-0**
Prerequisite: CE 406
The analysis of traffic and transportation engineering operations.
Messrs. Cribbins, Horn.

CE 516. Transportation Design **0-3**
Prerequisite: CE 406
The geometric elements of traffic and transportation engineering design.
Messrs. Cribbins, Horn.

CE 524. Analysis and Design of Masonry Structures **3-0**
Corequisite: CE 425
Analysis and design of arches, culverts, dams, foundations and retaining walls. Mr. Bramer.

CE 525, CE 526. Advanced Structural Analysis I, II **3-3**
Prerequisite: CE 425
Analysis of rigid frames and continuous structures; treatment of redundant members and secondary stresses. Messrs. Bigelow, Ely.

CE 527. Numerical Methods in Structural Analysis **0-3**
Prerequisite: CE 425
Newmark's numerical integration procedure and its applications; matrix operations, relaxation and iteration, finite difference method. Force and displacement methods, string polygon method. High-speed computation.
Messrs. Bigelow, McDonald.

CE 531. Experimental Stress Analysis **3-0**
Prerequisite: CE 425
Principles and methods of experimental analysis; dimensional analysis; applications to full-scale structures. Messrs. Bigelow, Bramer.

CE 534. Plastic Analysis and Design **0-3**
Prerequisite: CE 421
Analysis of steel structure behavior beyond the elastic limit; concept of design for ultimate load and the use of load factors. Analysis and design of component parts of frames. Methods of predicting strength and deformation behavior of structures loaded in the plastic range. Bracing and connecting requirements for frame. Mr. Bramer.

CE 535. Ultimate Strength Theory and Design **3-0**
Prerequisite: CE 422
Ultimate strength theories of axially loaded column, flexure, combined flexure and axial load, shear. Critical review of important research and their relationship with the development of design codes for reinforced concrete. Mr. Zia.

CE 536. Theory and Design of Prestressed Concrete **0-3**
Prerequisite: CE 422
The principles of prestressed concrete. Materials. Methods of prestressing. Loss of prestress. Design of beams for bending, shear and bond. Ultimate strength. Deflection. Composite beams. Continuous beams. Special topics. Design Projects. Mr. Zia.

CE 544. Foundation Engineering **3 or 3**
Prerequisite: CE 342
Subsoil investigations; excavations; design of sheeting and bracing systems; control of water; footing, grillage and pile foundations; caisson and cofferdam methods of construction; legal aspects of foundation engineering.
Messrs. Kashef, Wahls.

CE 547. Fundamentals of Soil Mechanics **3 or 3**
Prerequisite: EM 301
Physical and mechanical properties of soils governing their use for engineering purposes; stress relations and applications to a variety of fundamental problems. Mr. Wahls.

CE 548. Engineering Properties of Soils I **3-0**
Prerequisite: CE 342
The study of soil properties that are significant in earthwork engineering, including properties of soil solids, basic clay mineral concepts, classification, identification, plasticity, permeability, capillarity and stabilization. Laboratory work includes classification, permeability and compaction tests.
Mr. Kashef.

CE 549. Engineering Properties of Soils II **0-3**
Prerequisite: CE 548
Continuation of CE 548, including the study of compressibility, stress-strain relations and shear strength theories for soil. Laboratory work includes consolidation and shear strength tests. Mr. Kashef.

CE 570. (See BO 570. Sanitary Microbiology.)

CE 571. Theory of Water and Sewage Treatment **3-0**
Prerequisite: Graduate Standing
Study of the physical and chemical principles underlying water and sewage treatment processes; diffusion of gases, solubility, equilibrium and ionization, anaerobic and aerobic stabilization processes, sludge conditioning and disposal. Mr. Smallwood.

CE 572. Unit Operations and Processes in Sanitary Engineering **0-3**
Prerequisite: CE 571
Processes and operations in sanitary engineering; sedimentation, aeration, filtration, adsorption, coagulation, softening, sludge digestion, aerobic treatment of sewage. Mr. Smallwood.

CE 573. Analysis of Water and Sewage **3-0**
Corequisite: CE 571
Chemical and physical analysis of water and sewage and interpretation of results. Mr. Smallwood.

CE 574. Radioactive Waste Disposal **3 or 3**
Prerequisite: PY 407
Unit operations and processes employed in treatment and disposal of radioactive wastes. Mr. Smallwood.

CE 580. Flow in Open Channels **3 or 3**
Prerequisite: CE 483
The theory and applications of flow in open channels, including dimensional analysis, momentum-energy principle, gradually varied flow, high-velocity flow, energy dissipators, spillways, waves, channel transitions and model studies. Mr. Amein.

CE 591, CE 592. Civil Engineering Seminar **1-1**
Discussions and reports of subjects in Civil Engineering and allied fields.
Graduate Staff.

CE 598. Civil Engineering Projects **Credits by Arrangement**
Special projects in some phase of Civil Engineering.
Graduate Staff.

Courses for Graduates Only

CE 601. Transportation Planning **0-3**
Prerequisite: CE 515
The planning, administration, economics and financing of various transportation engineering facilities. Mr. Cribbins.

CE 602. Advanced Transportation Design **0-3**
Prerequisite: CE 516
Design of major traffic and transportation engineering projects.
Messrs. Cribbins, Horn.

CE 603. Airport Planning and Design **3-0**
Corequisite: CE 515
The analysis, planning and design of air transportation facilities.
Mr. Horn.

CE 604. Urban Transportation Planning **0-3**
Prerequisite: CE 515
Thoroughfare planning as related to land usage and urban master-planning.
Mr. Horn.

CE 623. Theory and Design of Arches **3-0**
Prerequisites: CE 422, CE 526
General theory of elastic arches. Boundary conditions and their effect on behavior of the arch. Single span, multiple span arches on elastic piers, influence lines of various functions under moving loads, economical layout of arches, design criteria for steel and concrete arches. Mr. Uyanik.

CE 624. Analysis and Design of Structural Shells and Folded Plates **0-3**
Prerequisites: CE 623, EM 511
Roof structures consisting of surfaces of revolution, both single and compound curved. Mebrane stresses, bending stresses at boundaries. Domes and cylindrical shells. Approximate and exact analyses. Design criteria. Folded plane structures of concrete plates and steel frames. Mr. Uyanik.

CE 625, CE 626. Advanced Structural Design I, II **3-3**
Prerequisite: CE 422
Corequisites: CE 525, CE 526
Complete structural designs of a variety of projects; principles of limit and prestress design. Mr. Uyanik.

CE 627. Design of Blast Resistant Structures **3-0**
Prerequisites: CE 526, EM 555
Sources, intensities, and methods of transmission of dynamic loads. Behavior of structures and structural elements subjected to dynamic forces. Design criteria and factor of safety. Design of surface and underground structures for nuclear blasts. Mr. McDonald.

CE 641, CE 642. Advanced Soil Mechanics **3-3**
Prerequisite: Graduate Standing
Theories of soil mechanics; failure conditions; mechanical interaction between solids and water, and problems in elasticity pertaining to earthwork engineering soil dynamics. Mr. Wahls.

CE 643. Hydraulics of Ground Water **3 or 3**
Prerequisite: Graduate Standing
Principles of ground water hydraulics; theory of flow through idealized porous media; the flow net solution; seepage and well problems.
Mr. Kashef.

CE 671. Advanced Water Supply and Sewerage **4-0**
Prerequisite: CE 484
Problems relating to the design of water supply and sewerage works.
Mr. Smallwood.

CE 672. Advanced Water and Sewage Treatment **0-4**
Prerequisite: CE 484
Problems relating to the treatment of water and sewage.
Mr. Smallwood.

CE 673. Industrial Water Supply and Waste Disposal **3 or 3**
Corequisite: CE 571
Water requirements of industry and the disposal of industrial wastes.
Mr. Smallwood.

CE 674. Stream Sanitation **3 or 3**
Corequisite: CE 571
Biological, chemical and hydrological factors that affect stream sanitation and stream use. Mr. Smallwood.

CE 699. Civil Engineering Research **Credits by Arrangement**
Independent investigation of an advanced Civil Engineering problem; a report of such an investigation is required as a graduate thesis.
Graduate Staff.

DEPARTMENT OF CROP SCIENCE

Graduate Faculty

Professors: Paul Henry Harvey, *Head,* Douglas Scales Chamblee, Dan Ulrich Gerstel, Walton Carlyle Gregory, Guy Langston Jones, Kenneth Raymond Keller, Glenn Charles Klingman, Roy Lee Lovvorn, Philip Arthur Miller, Robert Parker Moore, Donald Loraine Thompson, Joseph Arthur Weybrew

Professor Emeritus: Gordon Kennedy Middleton

Associate Professors: Charles A. Brim, Will Allen Cope, John Wesley Dudley, Donald Allen Emery, Harry Douglass Gross, William Mason Lewis, Jackson R. Mauney, Donald Edwin Moreland, Lyle L. Phillips, Luther Shaw, David Harry Timothy, Robert Phillip Upchurch

Assistant Professors: William Best Gilbert, Joshua Alexander Lee, Darrell Alvin Miller, Charles Franklin Murphy, Edward Carroll Sisler, Jerome Bernard Weber, David C. Whitenberg

The Department of Crop Science offers to students interested in crop science training leading to the Master of Science and Doctor of Philosophy

degrees in the fields of plant breeding, crop production, forage crops ecology, weed control, and plant chemistry. For students who wish a general training, the Master of Agriculture degree is offered.

Excellent facilities for graduate training are available. Each student is assigned office and laboratory space. In addition, many special facilities are available such as preparation rooms for plant and soil samples, cold storage facilities for plant material, air-conditioned rooms for studying the physical properties of cotton fiber and tobacco leaf, and soil and plant analytical service laboratories. Greenhouse space and growth control chambers are provided for projects which require special facilities. Sixteen farms are owned and operated by the State for research investigations. These farms are located throughout the State and include a wide variety of soil and climatic conditions needed for experiments in plant breeding, crop management, forage ecology, and weed control.

Strong supporting departments greatly increase the graduate students' opportunities for a broad and thorough training. Included among those departments in which graduate students in crop science work cooperatively or obtain instructions are botany, chemistry, genetics, horticultural science, mathematics, plant pathology, entomology, soil science, and statistics.

In North Carolina, a state which derives 80 per cent of its agricultural income from farm crops, the opportunities for the well trained agronomist are exceedingly great. The recipients of advanced degrees in crop science at North Carolina State are found in positions of leadership in research and education throughout the nation and the world.

Courses for Advanced Undergraduates

CS 413. Plant Breeding **0-3**
Prerequisite: GN 411
The application of genetic principles to the improvement of economic plants, including discussions of the methods employed in the development and the perpetuation of desirable clones, varieties, and hybrids.

CS 414. Weeds and Their Control. **3-0**
Prerequisite: CH 220 or Equivalent
Principles involved in cultural and chemical weed control. Discussions on chemistry of herbicides and the effects of the chemicals on the plant. Identification of common weeds and their seeds is given.

Courses for Graduates and Advanced Undergraduates

CS 511. Tobacco Technology **0-2**
Prerequisites: CS 311, BO 421 or Equivalent
A study of special problems concerned with the tobacco crop. The latest research problems and findings dealing with this important cash crop will be discussed. Mr. Jones.

CS 512. Grassland Dynamics **0-2**
Prerequisites: BO 421, ZO 301 or Equivalent
A discussion of forage production practices of national and international importance. An attempt will be made to relate the seemingly divergent

practices to fundamentals of physiology and ecology. The dynamic relationship among soil, plant, animal and man, as it affects production practices and research, will be emphasized. (Offered in 1964-65 and alternate years.) Mr. Gross.

CS 541. (GN 541 or HS 541) Plant Breeding Methods **3-0**
Prerequisites: GN 512, ST 511 Recommended
An advanced study of methods of plant breeding as related to principles and concepts of inheritance. Messrs. Haynes, Timothy.

CS 542. (GN 542 or HS 542) Plant Breeding Field Procedures **2 in Summer Sessions**
Prerequisite: CS 541 or GN 541 or HS 541
Laboratory and field study of the application of the various plant breeding techniques and methods used in the improvement of economic plants. Mr. Harvey.

CS 591. Special Problems **Credits by Arrangement**
Prerequisite: Admitted Only With Consent of Instructor
Special problems in various phases of Crop Science. Problems may be selected or will be assigned. Emphasis will be placed on review of recent and current research. Graduate Staff.

Courses for Graduates Only*

CS 611. Forage Crop Ecology **0-2**
Prerequisites: CS 412, BO 441
A study of the effect of environmental factors on the growth of forage crops. Attention will be given to methods of research in forage ecology. Mr. Chamblee.

CS 612. Special Topics in Weed Control **0-2**
Prerequisites or Corequisites: CS 414, CH 223, BO 534
Detailed examination of current concepts and literature of weed control. The chemistry, physiology, ecology, taxonomy, microbiology, equipment, and techniques used in weed control research will be discussed. Graduate Staff.

CS 613. (GN 613 or HS 613) Plant Breeding Theory **0-3**
Prerequisites: CS 541 or Equivalent, GN 513, ST 512 (A Course in Quantitative Genetics Recommended.)
A study of theoretical bases for plant breeding procedures with special emphasis on the relationship between type and source of genetic variability, mode of reproduction and effectiveness of different selection procedures. The latest experimental approaches to plant breeding will be discussed as well as standard procedures. Mr. Dudley.

CS 690. Seminar **1-1**
Prerequisite: Graduate Standing
Scientific articles, progress reports in research, and special problems of interest to agronomists reviewed and discussed.
A maximum of two credits is allowed toward the Master's degree, however, additional credits toward the doctorate are allowed. Graduate Staff.

* Students are expected to consult the instructor before registration.

CS 699. Research **Credits by Arrangement**
Prerequisite: Graduate Standing
A maximum of two credits is allowed towards the Master's degree, but no restrictions toward the doctorate. Graduate Staff.

DEPARTMENT OF ECONOMICS

Graduate Faculty

Professors: Ernst W. Swanson, *Head,* Bernard Martin Olsen
Associate Professors: Louis A. Dow, Gerald Garb, Cleon Wallace Harrell
Assistant Professor: Ching Sheng Shen

No graduate degrees are offered in economics at North Carolina State. The courses listed below are eligible for graduate credit when they form a part of an approved graduate program in other departments. Economics may serve as a minor field.

Courses for Advanced Undergraduates

EC 401, EC 402. Principles of Accounting **3-3**
Fundamental principles of accounting theory and practice; the analysis and recording of business transactions; explanation and interpretation of the structure, form and use of financial statements.

EC 407. Business Law I **3 or 3**
Prerequisite: EC 201 or EC 205
A course dealing wih elementary legal concepts, contracts, agency, negotiable instruments, sales of personal property, chattel mortgages, partnerships, corporations, suretyship and bailments, insurance.

EC 408. Business Law II **3 or 3**
Prerequisite: EC 407
Deals with real property, mortgages on urban and farm lands, landlord and tenant, requirements for valid deed, insurance law, wills, suretyship and conditional sales.

EC 409. Accounting for Production Costs **3-3**
Prerequisite: EC 312
An introduction to accounting problems peculiar to manufacturing, fabrication, and construction-type enterprises. Cost determination and allocation of costs for materials, labor, and overhead to the various units of product. Estimating and cost control in the production and manufacturing process. Special emphasis to be placed on managerial analysis and interpretation of cost data.

EC 410. Industry Studies **3-0**
Prerequisite: EC 201 or EC 205
An analysis of organization, market structure, and competitive behavior in specific industries using the tools of the economist as a guide to pertinent factors and their significance. The course will be organized along the lines of intensive but broadly-relevant case-studies.

EC 411. Marketing Methods **3-3**
Prerequisite: EC 201 or EC 205
Marketing institutions and their functions and agencies; retailing; market analysis; problems in marketing.

EC 413. Competition, Monopoly, and Public Policy **3-3**
Prerequisite: EC 201 or EC 205, EC 301 Recommended But Not Required
An analysis of the effect of modern industrial structure on competitive behavior and performance, in the light of contemporary price theory and the theory of workable competition. A critical evaluation of the legislative content, judicial interpretation, and economic effects of the antitrust laws.

EC 414. Tax Accounting **3 or 3**
Prerequisite: EC 312 or EC 401
An analysis of the Federal tax laws relating to the individual and business. Determining and reporting income. Payroll taxes and methods of reporting them. Actual practice in the preparation of income tax returns.

EC 420. Corporation Finance **3 or 3**
Prerequisite: EC 201 or EC 205
Financial instruments and capital structure; procuring funds; managing working capital; managing corporate capitalization; financial institutions and their work.

EC 425. Industrial Management **3-0**
Prerequisite: Junior Standing
Principles and techniques of modern scientific management; relation of finance, marketing, industrial relations, accounting, and statistics to production; production planning and control; analysis of economic, political and social influences on production.

EC 426. Personnel Management **0-3**
Prerequisite: Junior Standing
The scientific management of manpower, from the viewpoint of the supervisor and the personnel specialist. A study of personnel policy and a review of the scientific techniques regarding the specific problems of employment, training, promotion, transfer, health and safety, employee services, and joint relations.

EC 431. Labor Problems **3 or 3**
Prerequisite: Junior Standing
An economic approach to labor problems including wages, hours, working conditions, insecurity, substandard workers, minority groups, social security, and public policy relative to these problems.

EC 432. Industrial Relations **3 or 3**
Prerequisite: Junior Standing
Collective bargaining. Analysis of basic labor law and its interpretation by the courts and governmental agencies. An examination of specific terms of labor contracts and their implications for labor and management. An examination of labor objectives and tactics and management objectives and tactics. Problems of operating under the labor contract.

EC 440. Economics of Growth **0-3**
Prerequisite: EC 302
An examination of the institutional background required for national

economic development. The conditions apparent for past growth of nations are compared with conditions obtaining in presently retarded nations. Conclusions are drawn from this comparison to provide an introduction to theoretical models of growth.

EC 442. Evolution of Economic Ideas **0-3**
Prerequisite: EC 201 or EC 205
An analysis of the development of economic thought and method during the past two centuries. Economics considered as a cumulative body of knowledge, in a context of emerging technology, changing institutions, pressing new problems, and the growth of science.

EC 446. Economic Forecasting **3-0**
Prerequisite: EC 201 or EC 205, EC 302 Recommended But Not Required
An examination of the basic principles and techniques of economic forecasting with strong emphasis upon the economic models upon which forecasting is based.

EC 448. International Economics **3-0**
Prerequisites: EC 201, EC 202, EC 302 Recommended
A study of international economics, including trade, investment, monetary relations, and certain aspects of economic development. Emphasis upon analytical and policy approaches, although some institutional material is included.

EC 450. Economic Decision Processes **0-3**
Prerequisites: EC 201 or EC 205 and MA 202 or MA 212
An analysis of processes for decision making by individuals and groups. Linear programming, probability, and game theory in the light of a general theory of decision.

EC 490, EC 491. Senior Seminars in Economics **3 or 3**
Prerequisite: Consent of Instructors
The terminal courses in undergraduate study of economics. The student is assisted in summarizing his training, and in improving his capacity to recognize problems and to select logically consistent means of solving the problems. This is done on a small-group and individual basis.

Courses for Graduates and Advanced Undergraduates

EC 501. Intermediate Economic Theory **3-0**
Prerequisite: EC 301 or AGC 212, or Equivalent
An intensive analysis of the determination of prices and of market behavior, including demand, cost and production, pricing under competitive conditions, and pricing under monopoly and other imperfectly competitive conditions. Messrs. Dow, Garb, Shen.

EC 502. Money, Income, and Employment **0-3**
Prerequisite: EC 302 or EC 501, or Equivalent
A study of the methods and concepts of national income analysis with particular reference to the role of monetary policy in maintaining full employment without inflation. Messrs. Garb, Olsen, Shen.

EC 510. (PS 510) Public Finance **3 or 3**
Prerequisite: EC 201 or EC 205
A survey of the theories and practices of governmental taxing, spending, and borrowing, including intergovernmental relationships and administrative practices and problems. Mr. Block.

EC 525. Management Policy and Decision Making **3-0**
Prerequisites: Nine Hours in Economics and Related Courses and Consent of Instructor.
A review and consideration of modern management processes used in making top-level policies and decisions. An evaluation of economic, social and institutional pressures, and of the economic and non-economic motivations, which impinge upon the individual and the organization. The problem of coordinating the objectives and the mechanics of management is examined. Messrs. Bartley, Wood.

EC 531. Management of Industrial Relations **0-3**
Prerequisites: Nine Hours in Economics and Related Courses, Consent of the Instructor
A seminar course designed to round out the technical student's program. Includes a survey of the labor movement organization and structure of unions, labor law and public policy, the union contract, the bargaining process, and current trends and tendencies in the field of collective bargaining. Messrs. Bartley, Wood.

EC 541. Origins of the United States' Economy **3-0**
Prerequisites: Senior or Graduate Standing, EC 302, HI 261, or HI 333, or Equivalent
A seminar on growth and development of American economic institutions. Emphasis is placed on the relationship between the growth of the economy of the United States and theories of economic development. Mr. Olsen.

EC 550. Mathematical Models in Economics **3 or 3**
Prerequisites: EC 201 or EC 205, MA 202 or MA 212, EC 450 Recommended But Not Required
An introductory study of economic models emphasizing their formal properties. The theory of individual economic units is presented as a special case in the theory of inductive behavior. Mathematical discussions of the theory of the consumer, the theory of the firm, and welfare economics will show the relevance of such topics as constrained maxima and minima, set theory, partially and simply ordered systems, probability theory, and game theory to economics. Mr. Harrell.

EC 552. Econometrics **0-3**
Prerequisites: EC 201 or EC 205, MA 202 or MA 212, MA 405, ST 362
Recent developments in the theory of production, allocation, and organization. Optimal combination of integrated productive processes within the firm. Applications in the economics of industry and of agriculture.
Messrs. Harrell, Stober.

EC 555. Linear Programming **3-3**
Prerequisites: EC 201 or EC 205, MA 202 or MA 212, MA 405
Recent developments in the theory of production, allocation, and organization. Optimal combination of integrated productive processes within the firm. Applications in the economics of industry and of agriculture.
Messrs. Harrell, Garb.

EC 590, EC 591. Seminar in Special Economic Topics **3 or 3**
Prerequisite: Consent of Instructor.
Topics presented by a visiting professor or special lecturer. This course will be offered from time to time as distinguished visiting scholars are available.

Courses for Graduates Only

EC 601. Advanced Economic Theory **3 or 3**
Prerequisite: EC 501 or Equivalent
A rigorous examination of contemporary microeconomic theory.
Messrs. Dow, Garb, Shen, Swanson.

EC 602. (AGC 602) Monetary and Employment Theory **3 or 3**
Prerequisite: EC 502 or Equivalent
The course consists of an analysis of the forces determining the level of income and employment; a review of some of the theories of economic fluctuations; and a critical examination of a selected macroeconomic system.
Messrs. Garb, Tolley.

EC 603. History of Economic Thought **3-3**
Prerequisite: EC 442 or EC 501, or Equivalent
A systematic analysis of the development and cumulation of economic thought, designed in part to provide a sharper focus and more adequate perspective for the understanding of contemporary economics.
Messrs. Garb, Olsen, Swanson.

EC 605. Research in Economics **Credits by Arrangement**
Prerequisite: Graduate Standing
Individual research in economics, under staff supervision and direction.
Graduate Staff.

EC 640. Theory of Economic Growth **3 or 3**
Prerequisite: EC 440 or EC 502, or Equivalent
Several theoretical models of economic growth are compared and analyzed. Contemporary developments in the theory of national economic growth are studied and evaluated for consistency with older theories. Mr. Olsen.

EC 648. Theory of International Trade **0-3**
Prerequisite: EC 448 or EC 501, or Equivalent
A consideration, on a seminar basis, of the specialized body of economic theory dealing with the international movement of goods, services, capital, and payments. Also, a theoretically-oriented consideration of policy.
Mr. Swanson.

EC 650. Economic Decision Theory **3-0**
Prerequisites: EC 501 or Equivalent, EC 550 or EC 555
Study of general theories of choice. Structure of decision problems; the role of information; formulation of objectives. Current research problems.
Mr. Harrell.

EC 655. Topics in Mathematical Economics **3 or 3**
Prerequisites: EC 501 or Equivalent, EC 550 or EC 555
A seminar and research course devoted to recent literature and developments in mathematical economics. Messrs. Garb, Harrell.

EC 665. Economic Behavior of the Organization **0-3**
Prerequisites: EC 501 or Equivalent, Consent of Instructor
This seminar will apply methods and findings derived from the behavioral sciences to the economic behavior of the organization, particularly the business firm. Among the approaches which may be utilized are organization theory, information theory, reference group theory, and decision theory.
Messrs. Swanson, Harrell.

SCHOOL OF EDUCATION*

James Bryant Kirkland, *Dean*
Professor: Herbert Elvin Speece
Associate Professor: Norman M. Chansky

The School of Education offers graduate programs leading to the master's degree for students majoring in Agricultural Education, Industrial Arts Education, Industrial Education, Occupational Information and Guidance, and Industrial Psychology. Graduate students in education may pursue programs leading to the degree of Master of Science or Master of Education. Both degrees are recognized by the State Department of Education.

The Master of Science degree is regarded as a research degree and as preparation for further graduate study. Programs leading to the Master of Science degree are planned to include a major (twenty credit hours) in some specialized area of education and minor (ten or more credit hours) in some other field such as psychology or agricultural economics. If two minors are chosen, a minimum of six credits will be required in each.

A reading knowledge of one modern foreign language is required. A thesis representing an original investigation in the major field must be prepared.

The Master of Education degree is designed to meet the needs of students who are preparing themselves for teaching in the secondary schools. The program of study meeting the requirements for the professional degree differs from that for the Master of Science degree in that in the former a wider latitude is permitted in the choice of course work outside the major.

A problem may be substituted for a thesis if, in the opinion of the student's advisory committee, this alternative contributes maximally to the student's objective.

A knowledge of a foreign language is not required to meet the requirements for the professional degree.

The School of Education is located in Tompkins Hall where laboratories and research facilities are provided for graduate study.

A limited number of teaching and research assistantships are available for qualified graduate students. National Defense Education Act loans are also available for graduate students needing financial aid.

* Following the School of Education's general write-up and description of courses are sections pertaining to the departments within the school.

General Courses

Courses for Graduates and Advanced Undergraduates

ED 501. Education of Exceptional Children **3-0**
Prerequisite: Six Hours in Education or Psychology
Discussion of principles and techniques of teaching the exceptional child with major interest on the mentally handicapped and slow learner. Practice will be given in curriculum instruction for groups of children, individual techniques for dealing with retarded children in the average classroom. Opportunity for individual work with an exceptional child will be provided.
Mr. Corter.

ED 502. Analysis of Reading Abilities **3 or 3**
Prerequisite: Six Hours in Education or Psychology
A study of tests and techniques in determining specific abilities; a study of reading retardation and factors underlying reading difficulties.
Mr. Rust.

ED 503. Improvement of Reading Abilities **3 or 3**
Prerequisite: Six Hours of Education or Psychology
A study of methods used in developing specific reading skills or in overcoming certain reading difficulties; a study of methods used in developing pupil vocabularies and work analysis skills; a study of how to control vocabulary burden of reading material. Mr. Rust.

ED 552. Industrial Arts in the Elementary School **3 or 3**
Prerequisites: Twelve Credits in Education and Consent of Instructor
This course is organized to help elementary teachers and principles understand how tools and materials and industrial processes may be used to vitalize and supplement the elementary school children's experiences. Practical children's projects along with the building of classroom equipment.
Mr. Hostetler.

ED 563. Effective Teaching **3 or 3**
Prerequisite: ED 411 or Equivalent
Analysis of the teaching-learning process; assumptions that underlie course approaches; identifying problems of importance; problem solution for effective learning; relationship of learning and doing; responsibility for learnings; evaluation of teaching and learning; making specific plans for effective teaching. Mr. Scarborough.

ED 595. **(See IA 595. Industrial Arts Workshop.)**

Courses for Graduates Only

ED 614. Modern Principles and Practices in Secondary Education **2 or 2**
Prerequisite: Twelve Hours in Education
Foundations of modern programs of secondary education purposes, curriculum, organization, administration, and the place and importance of the high school in the community in relation to contemporary social force.
Graduate Staff.

ED 615. Introduction to Educational Research **3-0**
Prerequisite: Twelve Hours in Education
An introductory course for students preparing for an advanced degree. The

purposes are: to assist the student in understanding the meaning and purpose of educational research and the research approach to problems, to develop students' ability to identify educational problems, and to plan and carry out research to solve these problems; to aid in the preparation of the research report. Special attention is given to tools and methods of research. Consideration is also given to the educator as a consumer of research.

Graduate Staff.

ED 665. Supervising Student Teaching **3 or 3**
Prerequisite: Twelve Hours in Education
A study of the program of student teaching in teacher education. Special consideration will be given the role of the supervising teacher including the following areas: planning for effective student teaching, observation and orientation, school community study, analysis of situation, evaluating student teacher, and coordination with North Carolina State.

Graduate Staff.

ED 699. Research **Credits by Arrangement**
Prerequisites: Fifteen Credits and Permission of the Advisor
Individual research on a specific problem of concern to the student.

Graduate Staff.

DEPARTMENT OF AGRICULTURAL EDUCATION

Graduate Faculty

Professors: Clarence Cayce Scarborough, *Head,* James Bryant Kirkland
Associate Professor: Lawrence William Drabick
Assistant Professor: Homer Edwin Beam
Adjunct Professor: Gerald Blaine James

The Department of Agricultural Education offers programs of study leading to the Master of Science and the Master of Education degrees. Graduate programs are designed to meet the needs of the individual student. The department emphasizes instruction that will prepare the student for the role of a local educational leader. In addition to agricultural education courses, programs include courses in rural sociology, agricultural economics and public administration. All programs emphasize research. As a part of the graduate program, each student must complete a thesis or a research problem.

In addition to the many resources available to all North Carolina State graduate students, agricultural education students have available administrative and supervisory personnel staff members of the State Department of Public Instruction which is located in Raleigh. The State Director and Associate Director of Vocational Education, former members of North Carolina State faculty, are available as consultants to graduate students in agricultural education. Other members of the State Department of Public Instruction staff are also available for consultation.

A limited number of assistantships are available. Preference is given to experienced educational leaders in the field.

Courses for Graduates and Advanced Undergraduates

ED 554. Planning Programs in Agricultural Education **3 or 3**
Prerequisite: ED 411 or Equivalent
Analysis of theory of planning and change. Consideration of the need for planning programs in Agricultural Education; objectives and evaluation of community programs; use of advisory groups; organization and use of facilities; role of the leader. Messrs. Beam, Scarborough.

ED 568. Adult Education in Agriculture **3 or 3**
Prerequisite: ED 411 or Equivalent
Designed to meet the needs of leaders in adult education. Opportunity to study some of the basic problems and values in working with adult groups. Particular attention will be given to the leadership role in educational programs for adults. Messrs. Beam, Scarborough.

ED 593. Special Problems **3 or 3**
Prerequisite: ED 411 or Equivalent
Opportunities for students to study current problems under the guidance of the staff. Graduate Staff.

Courses for Graduates Only

ED 617. Philosophy of Agricultural Education **3 or 3**
Prerequisite: ED 554 or Equivalent
An examination of educational philosophies and their relation to current educational programs in agricultural education. Mr. Scarborough.

ED 664. Supervision in Agricultural Education **3 or 3**
Prerequisite: ED 563 or Equivalent
Organization, administration, evaluation and possible improvement of supervisory practice; theory, principles and techniques of effective supervision in Agricultural Education at different levels. Mr. Scarborough.

ED 693. Advanced Problems **3 or 3**
Prerequisite: ED 558 or Equivalent
Study of current and advanced problems in the teaching and administration of educational programs; evaluation of procedures and consideration for improving. Graduate Staff.

ED 694. Seminar in Agricultural Education **1-1**
A critical review of current problems, articles, and books of interest to students of agricultural education. Graduate Staff.

DEPARTMENT OF INDUSTRIAL ARTS

Graduate Faculty

Professor: Ivan Hostetler, *Head*
Associate Professor: Talmage Brian Young

The Department of Industrial Arts offers graduate work leading to the Master of Science degree and the Master of Education degree. Industrial Arts majors may select one or two minors in such fields as guidance, psychology, sociology, or school administration.

Professional and laboratory courses are provided on the graduate level to assure a well-rounded program of graduate studies. Special emphasis is being given and special funds provided for the development of an Experimental Laboratory with specialized equipment which will be used exclusively by advanced undergraduate and graduate students for experimentation and research. The industrial arts facilities of the public schools are also available for research work.

Teaching and graduate assistantships are available each year for experienced teachers interested in pursuing graduate work. Loans may also be secured through the National Defense Education Act for graduate students.

Holders of Master's degrees in Industrial Arts Education are much in demand for supervisory and teaching positions in the public schools and colleges.

Courses for Graduates and Advanced Undergraduates

IA 510. Design for Industrial Arts Teachers **3 or 3**
Prerequisites: Six Hours of Drawing and IA 205 or Equivalent
A study of new developments in the field of design with emphasis on the relationship of material and form in the selection and designing of industrial arts projects. Graduate Staff.

IA 560. (ED 560) New Developments in Industrial Arts Education **3 or 3**
Prerequisites: Twelve Hours in Education and Teaching Experience
This course is a study of the new developments in industrial arts education. It is designed to assist teachers and administrators in developing new concepts and new content based on the changes in technology. They will be required to re-evaluate their programs in the light of these new concepts and the new content. Mr. Hostetler.

IA 570. Laboratory Problems in Industrial Arts **Maximum 6**
Prerequisites: Senior Standing and Permission of Instructor
Courses based on individual problems and designed to give advanced majors in industrial arts education the opportunity to broaden or intensify their knowledge and abilities through investigation and research in the various fields of industrial arts, such as metals, plastics, or ceramics.
Graduate Staff.

IA 592. Special Problems in Industrial Arts **Maximum 6**
Prerequisite: One Term of Student Teaching or Equivalent
The purpose of these courses is to broaden the subject matter experiences in the areas of industrial arts. Problems involving experimentation, investigation and research in one or more industrial arts areas will be required.
Graduate Staff.

IA 595. (ED 595) Industrial Arts Workshop **3-3**
Prerequisite: One or More Years of Teaching Experience
A course for experienced teachers, administrators and supervisors of industrial arts. The primary purpose will be to develop sound principles and practices for initiating, conducting and evaluating programs in this field. Enrollees will pool their knowledge and practical experiences and will do intensive research work on individual and group problems.
Graduate Staff.

Courses for Graduates Only

ED 630. Philosophy of Industrial Arts **2 or 2**
Prerequisite: Twelve Hours in Education
Required of All Graduate Students in Industrial Arts Education
Current and historical developments in Industrial Arts; philosophical concepts, functions, scope, criteria for the selection and evaluation of learning experiences, laboratory organization, student personnel program, community relationships, teacher qualifications, and problems confronting the industrial arts profession. Mr. Hostetler.

ED 635. Administration and Supervision of Industrial Arts **2 or 2**
Prerequisite: Twelve Hours in Education
A study of the problems and techniques of administration and supervision in the improvement of Industrial Arts in the public schools. Selection of teachers and their improvements in service and methods of evaluating industrial arts programs. Mr. Hostetler.

ED 692. Seminar in Industrial Arts Education **1-1**
Prerequisite: Graduate Standing
Reviews and reports on special topics of interest to students in Industrial Arts Education. Mr. Hostetler.

DEPARTMENT OF INDUSTRIAL EDUCATION

Graduate Faculty

Professor: Durwin M. Hanson, *Head,* Joseph T. Nerden

The Department of Industrial Education offers graduate work leading to the degrees of Master of Science and Master of Education. The rapid development of industrial and technical education in North Carolina and throughout the nation provides many opportunities for teachers and administrators who have earned advanced degrees.

The facilities at North Carolina State afford an excellent program of supporting courses at the graduate level in the related fields of science, mathematics, guidance, psychology, sociology, economics, statistics, and engineering. The prerequisite for graduate work in Industrial Education is a proficiency in the undergraduate courses required for the bachelor's degree in Industrial Education, or a substantial equivalent.

A limited number of teaching and research assistantships are available for qualified graduate students.

Courses for Graduates and Advanced Undergraduates

ED 516. Community Occupational Surveys **0-2**
Prerequisites: Six Credits in Education, Consent of Instructor
Methods in organizing and conducting local surveys and evaluation of findings in planning a program of vocational education.
Graduate Staff.

ED 521. Organization of Related Study Materials **3 or 3**
Prerequisite: ED 422
The principles of selecting and organizing both technical and general related instructional material for trade extension and industrial cooperative training classes.
Graduate Staff.

ED 525. Trade Analysis and Course Construction **3-0**
Prerequisites: ED 344, PSY 304
Principles and practices in analyzing occupations for the purpose of determining teaching content. Practice in the principles underlying industrial course organization based on occupational analysis covering instruction in skills and technology and including course outlines, job sequences, the development of instructional materials and schedules.
Graduate Staff.

ED 527. Philosophy of Industrial and Technical Education **0-3**
Prerequisites: ED 422, ED 440
A presentation of the historical development of industrial and technical education; the types of programs, philosophy, trends and problems of vocational-industrial education; study of Federal and State legislation pertaining to industrial education, practical nurse education and technical education.
Mr. Nerden.

ED 528. Principles and Practices in Industrial Cooperative Training **3 or 3**
Prerequisites: ED 422, ED 440
A study of the developments, the objectives, and principles of industrial cooperative training. The organization, promotion and management of programs in this area of vocational education.
Graduate Staff.

ED 529. Curriculum Materials Development **3-3**
Prerequisite: ED 525
Selection and organization of curricula used in vocational-industrial and technical education; development of curricula and instructional materials.
Mr. Hanson.

ED 591. Special Problems in Industrial Education **Maximum 6**
Prerequisites: Six Hours Graduate Work and Permission of Department Head
Directed study other than thesis problem to provide individualized study and analysis in a specialized area of trade, industrial or technical education.
Messrs. Hanson, Nerden.

Courses for Graduates Only

ED 609. Planning and Organizing Technical Educational Programs **3 or 3**
Prerequisites: PSY 304, ED 344, ED 420, ED 440, ED 516
Principles of planning and organizing technical education programs sponsored by Federal vocational acts. Professional course for coordinators and directors, with emphasis on the organization of post high school technical education level. Survey of needs, building plans, equipping and maintenance of buildings, financial structure, and personnel organization and management.
Messrs. Hanson, Nerden.

ED 610. Administration and Supervision of Vocational Education **3 or 3**
Prerequisites: PSY 304, ED 344, ED 420, ED 440 or Equivalent
Administrative and supervisory problems of vocational education; practices and policies of Federal and State offices; organization and administration of city and consolidated systems. Messrs. Hanson, Nerden.

ED 691. Seminar in Industrial Education **1-1**
Prerequisite: Graduate Standing or Permission of the Instructor
Reviews and reports of topics of special interest to graduate students in Industrial Education. The course will be offered from time to time in accordance with the availability of distinguished professors.
Messrs. Hanson, Nerden.

DEPARTMENT OF OCCUPATIONAL INFORMATION AND GUIDANCE

Graduate Faculty

Professor: Roy Nels Anderson, *Head*
Associate Professor: Charles G. Morehead

The Department of Occupational Information and Guidance has been training guidance and personnel workers for more than four decades. The first master's degree was awarded in 1926. The programs of graduate study are planned to develop a broad understanding of guidance and personnel services to be applied in various settings. It is most desirable for an applicant who wishes to specialize in guidance and personnel services to have had undergraduate course work in economics, education, psychology, sociology, or social work. Students accepted into the program are those who anticipate devoting full or part time to guidance and personnel work. Teachers, administrators and others who wish to increase their knowledge of guidance and personnel may enroll for courses as a graduate minor or for certification renewal.

Professional opportunities for placement in this field are on the increase. The department prepares students for positions as counselors in secondary schools, industrial education centers, colleges, community agencies, school or county guidance directors, rehabilitation counselors, employment counselors, placement interviewers, and personnel workers in higher education, business or industry, and State and Federal Government agencies. The student may specialize in one of several areas depending upon his career goals.

The master's program includes a core of guidance and personnel courses to be selected according to the student's vocational goals. Students may select their minor from the following areas: economics, psychology, sociology and anthropology. The master's degree program of the department meets the requirements for the Counselor's Certificate issued by the North Carolina State Department of Public Instruction, as well as counselor certification in many other states.

The Department of Occupational Information and Guidance has had a contract with the Office of Vocational Rehabilitation for the training of Rehabilitation Counselors, and has been awarded five Counseling and

Guidance Training Institutes under contract with the United States Office of Education as authorized by the National Defense Education Act of 1958.

The department also provides service courses in guidance and personnel for undergraduate students in the School of Education.

Courses for Graduates and Advanced Undergraduates

ED 520. Personnel and Guidance Services **3-0**
Prerequisite: Six Hours of Education or Psychology
An introduction to the philosophies, theories, principles, and practices of personnel and guidance services; the relationship of personnel services with the purposes and objectives of the school and the curriculum.

Mr. Morehead.

ED 524. Occupational Information **0-3**
Prerequisites: Six Hours of Education or Psychology and ED 520 or Equivalent
This course is intended to give teachers, counselors, placement workers, and personnel workers in business and industry an understanding of how to collect, classify, evaluate, and use occupational and educational information. This will include a study of the world of work, sources of occupational information, establishing an educational-occupational information library, using educational, occupational, and social information, and sociological and psychological factors influencing career planning.

Mr. Morehead.

ED 530. Group Guidance **3-0**
Prerequisites: Six Hours of Education or Psychology and ED 520 or Equivalent
This course is designed to help teachers, counselors, administrators, and others who work with groups, or who are responsible for group guidance activities, to understand the theory and principles of effective group work, to develop skill in using specific guidance techniques, and to plan and organize group activities in the secondary school and other institutions.

Mr. Morehead.

ED 533. Organization and Administration of Guidance Services **0-3**
Prerequisites: Graduate Standing and ED 520 or Equivalent
This course is designed for school guidance counselors, prospective counselors, personnel and guidance directors, and school administrators. The philosophy and scope of guidance and personnel services; the functions and responsibilities of personnel involved; basic principles and current practices in planning, developing, operating, and supervising guidance and personnel services will be studied. Administrative relationships, utilization of school staff, interrelationships of guidance services with instruction, and evaluation of guidance services will be considered.

Mr. Morehead.

ED 590. Individual Problems in Guidance **Maximum 6**
Prerequisite: Six Hours Graduate Work in Department or Equivalent
Intended for individuals or group studies of one or more of the major problems in guidance and personnel work. Problems will be selected to meet

the interests of individuals. The workshop procedure will be used whereby special projects and reports will be developed by individuals and by groups.
Messrs. Anderson, Morehead.

Courses for Graduates Only

ED 631. Educational and Vocational Guidance **3-0**
Prerequisite: Nine Hours from Following Fields—Economics, Education, Psychology or Sociology
This course aims to provide training for teachers who are part-time or full-time counselors, employment interviewers, social workers and personnel workers, who are aiding individuals with vocational adjustment problems. The course will cover the functions performed in vocation and educational guidance such as assembling and imparting occupational information, counseling regarding vocational and educational plans, the use of aptitude tests, placement in jobs and follow-up, and procedures in setting up services of vocational and educational guidance in schools, employment offices, and social services agencies. Mr. Anderson.

ED 633. Techniques of Counseling **0-3**
Prerequisite: Nine Hours from Following Fields—Economics, Education, Psychology or Sociology
This course is designed to aid the personnel worker in the secondary school, college, employment office, social agency to develop an understanding and to develop skill in counseling techniques; philosophies, theories, principles and practices of counseling will be considered. Students will become acquainted with counseling techniques through lectures, demonstrations, case histories and tape recordings. Attention will be given to both diagnosis and treatment.
Mr. Anderson.

ED 641. Laboratory and Practicum Experiences in Counseling **2-6**
Prerequisite: Advanced Graduate Standing
A practicum course in which the student participates in actual counseling experience under supervision in a school, college, social service agency, employment office, and business or industrial establishment. The student may observe and participate in some personnel and guidance services and may study the organization and administration of the program.
Messrs. Anderson, Morehead.

DEPARTMENT OF PSYCHOLOGY

Graduate Faculty

Professors: Howard G. Miller, *Head,* Key Lee Barkley, Harold Maxwell Corter
Associate Professors: Norman M. Chansky, John Oliver Cook, Joseph Clyde Johnson, Slater Edmund Newman, Paul James Rust
Assistant Professors: Thomas Sanderson Baldwin, Eugene Edwin Bernard, Donald W. Drewes, Robert E. Lubow
Adjunct Assistant Professor: Gilbert Gottlieb

The Department of Psychology offers courses leading to the Master of

Science degree. An industrial option includes courses in the application of scientific methods to the study of industrial behavior based on strong research training. An experimental option provides a program with major emphasis on the development of proficiency in experimental methodology in psychological research. Human factors and human engineering training may be elected as a part of the industrial or experimental options. A program is offered which provides professional competence in school psychology.

All programs are designed to provide the student with solid grounding in the basic areas of psychology. A set of required core courses includes statistics, social psychology, experimental psychology, psychology of personality, and the theory and method of measurement.

A minimum of thirty semester hours of graduate credit is required for the master's degree, but the actual graduate program for each student is determined on the basis of his individual needs, interests, and accomplishments and very likely will require hours in excess of this minimum.

Admission requirements for graduate study in the Department of Psychology are a minimum of twenty semester credit hours in undergraduate psychology, the maintenance of a "B" average in undergraduate psychology courses, satisfactory grades in other collegiate studies, and satisfactory references from faculty and others in regard to character and quality of work. In some cases provisional acceptance is granted where some of the requirements are not met.

The physical facilities for the training of graduate students in psychology include testing, statistics, general and human engineering laboratories.

In addition to teaching and basic research activities, the Department of Psychology carries on research for industrial, military and other organizations. To facilitate this activity, the Industrial Psychology Center has been established as a special organization within the department.

A limited number of research and teaching assistantships are available annually. These assistantships are usually based on one-third time assignments, but are also occasionally for one-half time.

Courses for Advanced Undergraduates

PSY 438. Industrial Psychology II **0-3**
Prerequisites: PSY 200, PSY 337
The application of psychological principles to the problems of modern industry; with particular emphasis on human relations and supervision.
Mr. Miller.

PSY 441. Human Factors in Equipment Design **0-3**
Prerequisites: PSY 200, PSY 337 recommended
Human factors in the design of machines and other equipment. Items of equipment are understood as extensions of man's capacity to sense, comprehend, and control his environment. Includes problems in the psychology of information, communication, control, and invention.
Mr. Baldwin.

PSY 464. Visual Perception for Designers **3-0**
Prerequisite: PSY 200
The nature of the seeing process and its relation to architecture, industrial

arts, and to the industrial engineering, and textile design fields. Topics include the basis of sight, perception of color and form, vision and illumination, psychological factors in visual design, and a unit of training planned to improve the student's ability to perceive visual form.

Mr. Bernard.

PSY 475. Child Psychology **0-3**
Prerequisite: PSY 200 or PSY 304
The development of the individual child of the elementary school age will be the inclusive object of study in this course. Emphasis will be placed upon the intellectual, social, emotional, and personality development of the child. Physical growth will be emphasized as necessary to an understanding of the psychological development of the pupil.

Mr. Barkley.

PSY 476. Psychology of Adolescence **2-2**
Prerequisite: PSY 200
Nature and source of the problems of adolescents in western culture; emotional, social, intellectual and personality development of adolescents.

Messrs. Barkley, Johnson.

PSY 490. Social Psychology **0-3**
Prerequisite: PSY 200
The individual in relation to social factors. Socialization, personality development, communication, social conflict and social change.

Messrs. Barkley, Miller.

Courses for Graduates and Advanced Undergraduates

PSY 501. Experimental Psychology **3-3**
Prerequisite: Nine Hours of Psychology
Experimental study of problems in general and theoretical psychology with particular emphasis on sensation and perception. Particular attention is paid to problem formulation, experimental design and experimental methods. Effective written and oral performance by the student is a basic objective.

Messrs. Barkley, Cook, Newman.

PSY 502. Physiological Psychology **3-0**
Prerequisites: Twelve Hours of Psychology, Including PSY 200, PSY 201
A survey of the physiological bases of behavior including the study of coordination, sensory processes, brain functions, emotions, and motivation.

Messrs. Bernard, Corter.

PSY 504. Advanced Educational Psychology **0-3**
Prerequisite: Six Hours in Psychology
A critical appraisal of current psychological findings that are relevant to educational practice and theory. Mr. Johnson.

PSY 511. Advanced Social Psychology **3-0**
Prerequisites: PSY 200, PSY 514
A study of social relationships and their psychological bases; emphasis on those aspects of behavior determined by personal interactions; work will involve analysis of representative research studies, and individual projects.

Mr. Miller.

PSY 514. Psychological Research Design **1-0**
Prerequisite: Graduate Standing in Psychology
The objectives of this course are to acquaint students with current developments in theory and research in several areas of psychological interests; to foster capability to derive experimentally testable hypotheses, and experimental tests of these hypotheses; to write and speak effectively about theory and experimentation in psychology. Graduate Staff.

PSY 530. Abnormal Psychology **0-3**
Prerequisites: PSY 200, PSY 302
A study of the causes, symptomatic behavior, and treatment of the major personality disturbances, emphasis also placed on preventive mental hygiene methods. Mr. Corter.

PSY 535. Tests and Measurements **3-3**
Prerequisite: Six Hours in Psychology
A study of standard tests with an emphasis on the selection and use of such instruments. Mr. Johnson.

PSY 550. Mental Hygiene in Teaching **3-0**
Prerequisite: Six Hours in Psychology
A survey of mental hygiene principles applicable to teachers and pupils; practical problems in prevention and treatment of psychological problems in schools; case studies and research.
Messrs. Barkley, Corter.

PSY 565. Industrial Management Psychology **3-3**
Prerequisite: Nine Hours of Psychology
A study of the application of behavioral science, particularly psychology and social psychology to organizational and management problems.
Mr. Miller.

PSY 570. Theories of Personality **3-0**
Prerequisite: Nine Hours in Psychology
A survey of modern theories of personality with some emphasis on intelligence and cognitive factors. Mr. Corter.

PSY 576. Developmental Psychology **0-3**
Prerequisites: Nine Hours in Psychology, including PSY 476 or PSY 475
A survey of the role of growth and development in human behavior; particularly of the child and adolescent periods. This course will pay particular attention to basic principles and theories in the area of developmental psychology. Mr. Johnson.

PSY 578. Individual Differences **3-0**
Prerequisite: Six Hours in Psychology
Nature, extent, and practical implications of individual differences and individual variation. Mr. Barkley.

PSY 591. Individual Intelligence Measurement **0-3**
Prerequisite: Psychology 570
A practicum in individual intelligence testing with emphasis on the Wechsler-Bellevue, Stanford-Binet, report writing, and case studies. Mr. Corter.

Courses for Graduates Only

PSY 604. Advanced Experimental Psychology: Learning and Motivation 3 or 3
Prerequisite: PSY 501 or Equivalent
The objectives of this course are to promote familiarity with the kinds of research currently being conducted within the areas of "learning and motivation;" to foster effective performance in writing, speaking and reading in this area, in the derivation of hypotheses capable of experimental test and in the design of experiments to test them.
Messrs. Cook, Newman.

PSY 606. Behavior Theory 0-3
Prerequisites: PSY 200, a Course in Learning, Experimental Psychology and Statistics
A study of the most fundamental considerations in behavior theory. Such topics as criteria of scientific meaningfulness, the nature of scientific explanation, the application of formal, logical techniques to theory analysis, the nature of probability, operationism, intervening variables, etc., will be covered. The aim of the course is to develop skill in handling theoretical concepts, the ability to analyze and evaluate theories, to deduce hypotheses from them, and to devise means of testing them. Mr. Cook.

PSY 607. Advanced Industrial Psychology I 3-0
Prerequisites: Nine Hours of Psychology and Statistics or Concurrent with Statistics
Application of scientific methods to the measurement and understanding of industrial behavior. Messrs. Baldwin, Drewes, Miller.

PSY 608. Advanced Industrial Psychology II 0-3
Prerequisite: PSY 607
Application of scientific methods to the measurement and understanding of industrial behavior. Messrs. Baldwin, Drewes, Miller.

PSY 610. Theories of Learning 0-3
Prerequisite: PSY 604
The objectives of this course are to promote learning of the theories currently used to explain how learning and forgetting occur so that testable consequences of these theories can be derived and so that the theories and their testable consequences are capably written and spoken about.
Messrs. Cook, Newman.

PSY 635. Psychological Measurement 0-3
Prerequisite: ST 511 or Equivalent and Twelve Hours of Psychology
Theory of psychological measurement. Statistical problems and techniques in test construction. Mr. Drewes.

PSY 690. Seminar in Industrial Psychology 3-3
Scientific articles, analysis of experimental designs in industrial psychology, and study of special problems of interest to graduate students in Industrial Psychology. Messrs. Baldwin, Drewes, Miller.

PSY 691. Personality Measurement 3-3
Prerequisites: PSY 570, PSY 571
Theory and practicum in individual personality testing of children and adults with emphasis on projective techniques, other personality measures, report writing and case studies. Mr. Corter.

PSY 693. Psychological Clinic Practicum **Maximum 12**
Prerequisite: Eight Hours in Psychology
Clinical participation in interviewing, counseling, psychotherapy and administration of psychological tests. Practicum to be concerned with adults and children. Mr. Corter.

PSY 699. Research in Psychology **Credits by Arrangement**
Individual or group research problems; a maximum of six credits is allowed toward the Master's degree. Graduate Staff.

DEPARTMENT OF ELECTRICAL ENGINEERING

Graduate Faculty

Professors: George Burnham Hoadley, *Head,* William John Barclay, Arthur Raymond Eckels, William Damon Stevenson, Jr., *Graduate Administrator*

Associate Professors: Norman Robert Bell, Edward George Manning, Wilbur Carroll Peterson

Assistant Professor: Robert Walter Lade

Visiting Professor: Makoto Itoh

The Department of Electrical Engineering offers the Master of Science and the Doctor of Philosophy degrees. Graduate work in electrical engineering at the first-year or master's level is limited to one or two areas of specialization. In the more advanced study for the doctorate a comprehensive understanding of all fields of electrical engineering is required, and specialization appears in the research problem undertaken.

Advanced courses of a general and fundamental nature, such as electrical network synthesis and electromagnetic waves, are recommended for all graduate students in electrical engineering, and are required of those who plan to carry their advanced studies to the level of the doctorate. Minor sequences of study in advanced mathematics or physics are planned to fit the needs of individual students.

The laboratories of the department are equipped for research in electronic circuits, in automatic controls, and in solid-state devices. Active research is in progress, especially in the solid-state area where our laboratory equipment makes possible the construction of a wide variety of solid-state devices.

Courses for Advanced Undergraduates

EE 401. Advanced Circuits and Fields **3-0**
Prerequisites: EE 302, MA 301
Required of Seniors in EE
Transient analysis of electric circuits by the Laplace transform method, the study of transient and sinusoidal steady-state response in terms of poles and zeros of network functions.

EE 402. Advanced Circuits and Fields **0-3**
Prerequisites: EE 302, MA 301
Required of Seniors in EE
A study of classical electric and magnetic field theory and its application to problems of electrical engineering. Consideration of electrostatics, radiation, and guided waves.

EE 411. Electrical Engineering Senior Seminar **1-0**
Prerequisite: Senior Standing
Required of Seniors in EE
Weekly meetings for the delivery and discussion of student papers on topics of current interest in Electrical Engineering.

EE 430. Essentials of Electrical Engineering **4-0**
Prerequisite: EE 301 or EE 332
Not Available to Undergraduates in Electrical Engineering
Essential theory of electric circuits, including electron tubes, solid state devices, transformers and rotating machines as needed to supply the electrical background for instrumentation and control theory. Intended primarily for graduate students who do not have an electrical engineering undergraduate degree.

EE 431. Electronic Engineering **3-0**
Prerequisites: EE 302, EE 314
Departmental Elective for Seniors
Comprehensive coverage of circuits and equipment using electronic devices; variable frequency effects; amplifiers, oscillators, modulators, detectors, waveshaping circuits, generators of non-linear waveforms; basic pulse techniques; principles of electronic analogue computers. Emphasis on quantitative analysis and engineering design.

EE 432. Communication Engineering **0-3**
Prerequisite: EE 431
Departmental Elective for Seniors in EE
Application of electronic circuits and equipment to communication systems. Generation and modulation of radio frequency power. Elements of complete systems, wave propagation, antennas, transmitters, receivers, television, radar, electronic navigation systems, noise, special applications.

EE 433. Electric Power Engineering **3-0**
Prerequisites: EE 301, EE 305
Departmental Elective for Seniors in EE
A study of industrial power supply and power factor correction; direct and alternating current motor characteristics, starting methods, dynamic braking and speed control; motor applications, and industrial control apparatus.

EE 434. Power System Analysis **0-3**
Prerequisites: EE 302, EE 305
Departmental Elective for Seniors in EE
Analysis of problems encountered in the long-distance transmission of electric power. Line parameters of the method of geometric mean distances. Circle diagrams, symmetrical components, and fault calculations. Elementary concepts of power system stability. Applications of digital computers to power-system problems.

EE 435. Elements of Control **3-0**
Prerequisites: EE 314 and EE 305, or EE 430
Departmental Elective for Seniors in EE
Introductory theory of open and closed loop control. Functions and performance requirements of typical control systems and system components. Dynamic analysis of error detectors, amplifiers, motors, demodulators, analogue components and switching devices. Component transfer characteristics and block diagram representation.

EE 438. Instrumentation in Nuclear Technology **0-3**
Prerequisites: Either EE 430 or EE 301 and EE 314; also MA 301
Departmental Elective for Seniors in EE
Required course in Nuclear Engineering, Instrumentation Option. Radiation detectors, pulse amplifiers, pulse shapers, amplitude discriminators, counters, coincidence circuits.

EE 440. Fundamentals of Digital Systems **0-3**
Prerequisite: EE 314 or EE 430
Departmental Elective for Seniors in EE
The basic theory of digital computation and control. Introduction to number systems, data handling, relay algebra, switching logic, memory circuits, the application of electronic devices to switching circuits and the design of computer control circuits.

Courses for Graduates and Advanced Undergraduates

EE 503. Linear Network Theory **3-0**
Prerequisites: EE 302, EE 314, MA 301, B Average in EE and MA
Analysis of linear networks, with emphasis on the system functions of the network in the frequency domain and response in the time domain.
Mr. Stevenson.

EE 504. Introduction to Network Synthesis **0-3**
Prerequisite: EE 503
A development of the methods of network synthesis of one-port and two-port passive structures based on partial fraction techniques.
Mr. Stevenson.

EE 506. Dynamical Analogies **0-3**
Prerequisites: EE 301 or EE 331; EM 312 or EM 301; MA 301; B Average in EE, EM and MA
A study of dynamic systems in various branches of engineering and science with emphasis on the similarities that exist among such integrated groups of devices. Analogous elements and quantities in these fields as determined from equations basic to each. Analytical formulation of system problems in acoustical, electrical, mechanical, and related fields and their solution by analog methods. Use of electronic analog computers for the solution of system problems. Mr. Eckels.

EE 507. Electromagnetics **0-3**
Prerequisites: EE 302, EE 314, MA 301; B Average in EE and MA
Basic principles of electromagnetic field theory in vector analysis formulation, including static electric and magnetic fields, Maxwell's equations and applications to guided waves. Graduate Staff.

EE 511. Electronic Circuits **3-0**
Prerequisites: EE 314 or EE 430, B Average in EE and MA
Solid-state and vacuum electronic devices in amplifiers, feedback systems, oscillators, modulators, switching and wave-shaping circuits. Generation of nonlinear waveforms; electronic instruments; circuits basic to electronic computers. Use of complex frequency concepts to obtain generalized response. Communication, power, and industrial applications. Synthesis of circuits to satisfy system requirements. Mr. Barclay.

EE 512. Communication Theory **0-3**
Prerequisites: EE 431, B Average in EE and MA
The frequency and time domain, modulation, random signal theory, autocorrelation, basic information theory, noise, communication systems.
Mr. Barclay.

EE 516. Feedback Control Systems **0-3**
Prerequisites: EE 401, EE 435
Departmental Elective for Seniors in EE
Study of feedback systems for automatic control of physical quantities such as voltage, speed and mechanical position. Theory of regulating systems and servo-mechanisms. Steady state and transient responses. Evaluation of stability. Transfer function loci and root locus plots. Analysis using differential equation and operational methods. System compensation and introduction to design. Mr. Peterson.

EE 517. Control Systems Laboratory **0-1**
Corequisite: EE 516
Laboratory study of feedback systems for automatic control of physical quantities such as voltage, speed and mechanical position. Characteristics of regulating systems and servo-mechanisms. The laboratory work is intended to contribute to an understanding of the theory developed in EE 516, Feedback Control Systems. Mr. Peterson.

EE 520. Fundamentals of Logic Systems **3-0**
Prerequisites: EE 314 or EE 430; B Average in EE and MA
A study of switching algebra, logic circuitry, systematic minimization, block diagrams, logic systems in computers, diode and transistor logic, symmetric functions, iterative networks, cascaded systems, sequential circuits, and pulsed operation. Mr. Bell.

EE 521. Digital Computer Technology and Design **0-3**
Prerequisite: EE 520
A study of the internal organization and structure of digital systems including toggle circuits, gates and pulse circuitry. Analysis and synthesis of the major components of computers, and their integration into a complete system. Mr. Bell.

EE 531. Introduction to Solid State Devices **3-0**
Prerequisites: EE 314 or EE 430 or PY 403; MA 301
The object of this course is to introduce the student to the microscopic phenomena responsible for the operation of solid state electronic devices. A qualitative description of the band model of solids is followed by a description of the transport properties of charge carriers. P-n junction diodes and

transistors, solar cells, controlled rectifiers, tunnel diodes, and unijunction transistors are treated along with more recently developed devices.
Mr. Lade.

EE 533. Transistor Circuits **3-0**
Prerequisites: EE 302, EE 314, B Average in EE and MA
A study of the application of transistors to linear and switching circuitry. The electrical response of such systems is considered in the light of certain physical characteristics of the transistor, in addition to the piecewise linear model. Device characteristics, temperature stability, cascaded amplifiers, and elementary switching circuits are treated. Mr. Manning.

EE 591, EE 592. Special Topics in Electrical Engineering **3-3**
Prerequisite: B Average in Technical Subjects
A two-semester sequence to develop new courses, and to allow qualified students to explore unusual areas. Graduate Staff.

Courses for Graduates Only

EE 611, EE 612. Electric Network Synthesis **3-3**
Prerequisite: EE 504
A study of modern network theory, with the emphasis on synthesis of both passive and active networks based on the work of Brune, Bode, Guillemin, Bott and Duffin, Darlington, Foster, Linville and many others. Both the realization problem and the approximation problem will be treated.
Mr. Hoadley.

EE 613. Advanced Feedback Control **3-0**
Prerequisite: EE 516
An advanced study of feedback systems for the control of physical variables. Analysis of follower systems and regulators, mathematical and graphical description of systems. Stability theory and performance criteria. Frequency response and root locus methods of analysis. System compensation and design. Synthesis of linear systems. Introductory analysis of non-linear systems. Mr. Peterson.

EE 615. Electromagnetic Waves **4-0**
Prerequisite: EE 507
Maxwell's equations applied to a study of the propagation of energy by electromagnetic waves. Vector and scalar retarded potentials, propagation in free space and material media, guided electromagnetic waves, common waveguides, skin effects, resonant cavities. Microwave network theory applied to measurement problems. Messrs. Barclay, Itoh.

EE 616. Microwave Electronics **0-4**
Prerequisite: EE 615
Frequency limitations of conventional electron tubes. Microwave power generation and control by interaction of electromagnetic fields with charged particles and molecular energy levels, and by non-linear reactances. Applications in klystrons, magnetrons, traveling-wave tubes, masers, and reactance amplifiers. Measurement problems and techniques in microwave region.
Mr. Barclay.

EE 617. Pulse, Switching, and Timing Circuits **3-0**
Prerequisites: EE 503, EE 512
Tube and transistor circuit techniques for the production, shaping, and control of nonsinusoidal wave forms. Fundamental circuits needed in pulse information systems, instrumentation, and computers. Mr. Barclay.

EE 618. Antennas and Propagation **0-4**
Prerequisite: EE 615
Electromagnetic wave theory applied to antennas and antenna arrays with emphasis on microwave frequencies. Calculation and measurement of directional characteristics, gain, field intensity, propagation via the ionosphere over various terrains, obstacle gain, gain height theory, forward scatter and other topics. Mr. Itoh.

EE 623. Electronic Properties of Solid State Materials **3-0**
Prerequisite: EE 531 or PY 552
A study of the electronic properties of solids. Consideration of the motion of electrons in periodic potentials leads directly to the study of the band theory and its consequences on the electrical and magnetic properties of materials. Beginning with the Boltzmann transport equations a phenomenological description of charge carrier flow is developed in terms of an effective mass tensor. Hot electron transport, radiative transition mechanisms and high field effects will be treated in some depth. Mr. Lade.

EE 624. Electronic Properties of Solid State Devices **0-3**
Prerequisite: EE 623
A study, in detail of the terminal properties of a large class of solid state devices. Boundary relationships at solid-state interfaces will be considered in considerable depth along with the determination of added carrier profiles in neutral and non-neutral bulk regions. The role of deep lying traps on device performance will be treated as an introduction to a class of space-charge-limited devices. The present technology of device fabrication will be discussed and demonstrated. Mr. Lade.

EE 641. Advanced Digital Computer Theory **0-3**
Prerequisite: EE 520
A study of the circuits and components of modern digital computers, including basic logic systems, codes, advanced systems of circuit logic, vacuum tube, transistor, and magnetic components. Memory devices, counters, converters, adders, accumulators, inputs, outputs, and computer control systems will be analyzed. Mr. Bell.

EE 642. Automata and Adaptive Systems **3-0**
Prerequisite: EE 520
The study of neural nets in natural systems, artificial nerve nets, pattern-recognition devices, artificial intelligence, goal-directed behavior, self-repairing machines, the logic of automata, and adaptive Boolean logic. Mr. Bell.

EE 643. Advanced Electrical Measurements **0-3**
Prerequisites: EE 503, EE 431
A critical analysis of circuits used in electrical measurements, with special attention to such topics as balance convergence, effects of strays, sensitivity, the use of feedback in electronic devices, automatic measuring systems, and digital measuring systems. Mr. Hoadley.

EE 645, EE 646. Advanced Electromagnetic Theory **3-3**
Prerequisites: EE 615 or PY 503, MA 512
A comprehensive study of electromagnetic theory with emphasis on field theory applications. Charges in both uniform and accelerated motion, field equivalence principles, anisopropic media, ferrite media, variational methods for waveguide discontinuities, periodic structures including Floquet's theorem, integral transform and function-theoretical techniques, solid state theory applied to quantum electronic devices. Mr. Itoh.

EE 691, EE 692. Special Studies in Electrical Engineering **3-3**
This course provides an opportunity for small groups of advanced graduate students to study, under the direction of qualified members of the professional staff, advanced topics in their special fields of interest.
Graduate Staff.

EE 695. Electrical Engineering Seminar **1-1**
Prerequisite: Graduate Standing in EE
A series of papers and conferences participated in by the instructional staff, invited guests, and students who are candidates for advanced degrees.
Mr. Eckels.

EE 699. Electrical Engineering Research **Credits By Arrangement**
Prerequisites: Graduate Standing in EE, and Approval of Adviser.
Graduate Staff.

DEPARTMENT OF ENGINEERING MECHANICS

Graduate Faculty

Professors: Patrick Hill McDonald, Jr., *Head,* *Robert Alden Douglas, Adolphus Mitchell
Associate Professors: John Edward Griffith, *Graduate Administrator,* Daniel Shou-Ling Wang
Assistant Professors: John Auert Edwards, John Frederick Ely, Edward D. Gurley

Affiliated Graduate Faculty

Associate Professors: Frederick Otto Smetana, James Clifford Williams, James T. Yen, Paul Zung Teh Zia, Carl Frank Zorowski
Assistant Professor: Michael Amein

The faculty of the Department of Engineering Mechanics offers a broad range of graduate courses both for its own students seeking advanced degrees and for inclusion in the graduate programs of students in allied areas of engineering and in the physical and mathematical sciences.

Graduate studies in Engineering Mechanics embrace four broad areas; namely, fluid mechanics, solid mechanics, continuum mechanics, and dynamics. Each of these areas is of considerable importance in current research, to the extent that professional demands in these areas by space-related industry and governmental agencies is second only to those for the electronics specialties. Professional interests of the faculty are represented by courses devoted to the elastic and plastic behavior of solids, viscous and compressible

* On leave, 1964-66

fluid flow, the generalized behavior of matter when described as a continuum, and in sequences devoted to the theory of periodic and aperiodic vibrations and to space mechanics.

Courses for individual programs may be chosen rather broadly from the listings indicated, and special attention is directed to the reservoir of courses appropriate to mechanics studies, selected from closely allied engineering specialties. Beginning graduate students ordinarily will choose a program to encompass several of the major areas, thus establishing a broad base for subsequent studies at the advanced graduate level which usually are concentrated about one particular area of research.

Graduate research in mechanics in any of the four major areas outlined may follow the lines of either analytical or experimental investigations. The development of new research techniques for both types of endeavors is of prime concern to the field of mechanics and the laboratory complex of Engineering Mechanics now includes four research laboratories. One of these is equipped for the study of fluid behavior of liquid metals, another for dynamic studies in viscoelasticity, still a third for research in fracture mechanics, and the fourth for static and dynamic studies in stress concentration. Whether a student is inclined toward analytical or toward experimental investigations, he ordinarily will gain experience in both types of endeavor prior to his independent research activities.

The faculty of Engineering Mechanics has submitted, for administrative approval, a proposal for a doctoral program to be inaugurated in July, 1964.

Courses for Graduates and Advanced Undergraduates

EM 501, EM 502. Continuum Mechanics I, II **3-3**
Prerequisites: EM 301, EM 303, ME 301, MA 405
The concepts of stress and strain are presented in generalized tensor form. Emphasis is placed on the discussion and relative comparison of the analytical models for elastic, plastic, fluid, viscoelastic, granular, and porous media. The underlying thermodynamic principles are presented, the associated boundary value problems are formulated and selected examples are used to illustrate the theory. Mr. Griffith.

EM 503. Theory of Linear Elasticity **3-0**
Prerequisites: EM 301, MA 301
The equations describing the linear elastic solid are used to illustrate the development of analytical models used to predict the behavior of solids. Studies in instability, wave propagation, thermal stresses, and fracture mechanics illustrate the viewpoints employed for varied physical phenomena. Mr. Douglas.

EM 504. Mechanics of Ideal Fluids **3-0**
Prerequisites: EM 430 or EM 304
Corequisite: MA 513
Basic equations of ideal fluid flow; potential and stream functions; vortex dynamics; body forces due to flow fields; methods of singularities in two-dimensional bows; analytical determination of potential functions: conformal transformations; free-streamline flows. Messrs. Amein, Edwards.

EM 505. Mechanics of Viscous Fluids I **3-0**
Prerequisites: EM 430 or EM 304
Corequisite: MA 532
Equations of motion of a viscous fluid (Navier-Stokes Equations); general properties of the Navier-Stokes equations; some exact solutions of the Navier-Stokes equations; boundary layer equations; some approximate methods of solution of the boundary layer equations; laminar boundary layers in axi-symmetric and three-dimensional flows; unsteady laminar boundary layers. (Offered in 1964-65 and alternate years.)
Messrs. Amein, Edwards.

EM 506. Mechanics of Compressible Fluids I **3-0**
Prerequisites: EM 430 or EM 304, ME 302
Corequisite: MA 532
Introduction to compressible fluid flow; isentropic, one-dimensional flow; Rayleigh and Fanno line flows; generalized one-dimensional flow; normal shock waves; introduction to multi-dimensional, compressible flow. (Offered in 1963-64 and alternate years.) Messrs. Edwards, Yen.

EM 509. Space Mechanics I **3-0**
Prerequisites: EM 302, EM 304
Corequisite: MA 511
The application of mechanics to the analysis and design of orbits and trajectories. Trajectory computation and optimization; space maneuvers; reentry trajectories; interplanetary guidance. (Offered in 1964-65 and alternate years.) Mr. Clayton.

EM 510. Space Mechanics II **0-3**
Prerequisites: EM 509, MA 511
Continuation of EM 509. The analysis and design of guidance systems. Basic sensing devices; the characteristics of an inertial space; the theory of stabilized platforms; terrestrial inertial guidance. (Offered in 1964-65 and alternate years.) Mr. Clayton.

EM 511. Theory of Plates and Shells **3-0**
Prerequisites: EM 301, MA 441
Bending theory of thin plates; geometry of surfaces and stresses in shells. Various methods of analysis are discussed and illustrated by problems of practical interest. Messrs. Ely, Wang.

EM 551. Advanced Strength of Materials **3-0**
Prerequisite: EM 301
Stresses and strains at a point; rosette analysis; stress theories, stress concentration and fatigue; plasticity; inelastic, composite and curved beams; prestress energy methods; shear deflections; buckling problems and column design; and membrane stresses in shells. Mr. Mitchell.

EM 552. Elastic Stability **0-3**
Prerequisites: MA 301, MA 405, EM 551
A study of elastic and plastic stability. The stability criterion as a determinant. The energy method and the theorem of stationary potential energy. The solution of buckling problems by finite differences and the calculus of

variations. The application of successive approximations to stability problems. Optimization applied to problems of aeroelastic and civil engineering structures. Messrs. Mitchell, Zia.

EM 555. Dynamics I **0-3**
Prerequisites: EM 301, MA 405
The theory of vibrations from the Lagrangian formulation of the equations of motion. Free and forced vibrations with and without damping, multiple degrees of freedom, coupled motion, normal mode vibrations, wave propagation in solid bodies. (Offered in 1963-64 and alternate years.)
Mr. Clayton.

EM 556. Dynamics II **0-3**
Prerequisites: EM 301, MA 405
The dynamics of particles and rigid bodies by the use of formulations of the laws of mechanics due to Newton, Euler, Lagrange, and Hamilton. Accelerated reference frames, constraints, Euler's angles, the spinning top, the gyroscope, precession, stability, phase space, and nonlinear oscillatory motion. (Offered in 1963-64 and alternate years.) Mr. Clayton.

Courses for Graduates Only

EM 601, EM 602. Unifying Concepts in Mechanics I, II **3-3**
Prerequisite: PY 601
Generalized treatment of the fundamental equations and boundary value problems of continuous and non-continuous media. Use is made of contemporary developments in irreversible thermodynamics, statistical mechanics, and electrodynamics to provide a unified foundation for the development of principles governing the dynamic and thermodynamic behavior of elastic, plastic and visco-elastic solids, viscous fluids and rheological media. (Offered in 1963-64 and alternate years.) Messrs. Griffith, McDonald.

EM 604. Theory of Plasticity **0-3**
Prerequisite: EM 503
Analytical models are developed to represent the behavior of deformable solids in the plastic regime. Conditions of yielding and fracture which initiate and terminate plastic behavior are studied, with the special stress-strain relationships necessary in plasticity. The hyperbolic equations and slip-line fields characteristic of plane strain theory are developed.
Messrs. Douglas, Zorowski.

EM 611. Mechanics of Compressible Fluids II **0-3**
Prerequisite: EM 506
Continuation of EM 506; linearized theory of two-dimensional flow; method of characteristics for two-dimensional supersonic flow; oblique shock waves; unsteady one-dimensional flow; shock-wave boundary layer interactions; transonic flow. (Offered in 1963-64 and alternate years.)
Messrs. Edwards, Smetana.

EM 612. Mechanics of Viscous Fluids II **0-3**
Prerequisite: EM 505
Continuation of EM 505; phenomenological theories of turbulence; turbulent flow in ducts and pipes; turbulent boundary layer with and without

pressure gradient; compressible boundary layer; boundary layer control; free viscous flow. (Offered in 1964-65 and alternate years.)
Messrs. Amein, Williams.

EM 695. Experimental Methods in Mechanics **0-3**
Prerequisite: Consent of Instructor
The study of specialized experimental techniques utilized in contemporary research in the areas of Mechanics. Messrs. Douglas, Edwards, McDonald.

EM 697. Seminars in Mechanics **1 to 3-1 to 3**
Prerequisites: Graduate Standing and Consent of Adviser
The discussion and development of theory relating to contemporary research in the frontier areas of Mechanics. Mr. McDonald.

EM 698. Special Topics in Mechanics **3 to 9**
The study, by small groups of graduate students under the direction of members of the faculty, of topics of particular interest in various advanced phases of Mechanics. Graduate Staff.

EM 699. Research in Mechanics **3 to 6**
Individual research in the field of Mechanics. Graduate Staff.

Courses in Allied Areas

CHE 551	**Thermal Problems in Nuclear Engineering**
CE 580	**Flow in Open Channels**
CE 525, CE 526	**Advanced Structural Analysis I, II**
CE 534	**Plastic Analysis and Design**
CE 535	**Ultimate Strength Theory and Design**
CE 547	**Fundamentals of Soil Mechanics**
EE 506	**Dynamical Analogies**
MA 555 (PY 555)	**Principles of Astrodynamics**
ME 515	**Experimental Stress Analysis**
ME 516	**Photoelasticity**
ME 521	**Aerothermodynamics**
ME 541, ME 542	**Aerodynamic Heating**
ME 554	**Advanced Aerodynamic Theory**
ME 581, ME 582	**Hypersonic Aerodynamics**
MIM 561	**Advanced Structure and Properties of Materials**
CE 624	**Analysis and Design of Structural Shells and Folded Plates**
CE 625, CE 626	**Advanced Structural Design I, II**
CE 627	**Design of Blast Resistant Structures**
CE 641, CE 642	**Advanced Soil Mechanics**
CE 643	**Hydraulics of Ground Water**
MIC 605, MIC 606	**Crystal Structures**
MA 605	**Non-Linear Differential Equations**
MA 632, MA 633	**Operational Mathematics I, II**
MA 661, MA 662	**Tensor Analysis I, II**
ME 606	**Advanced Gas Dynamics**
ME 611, ME 612	**Advanced Machine Design I, II**
ME 613	**Mechanics of Machinery**
ME 614	**Mechanical Transients and Machine Vibrations**
ME 615, ME 616	**Aeroelasticity I, II**
ME 617	**Plates and Shells in Mechanical Design**
ME 652	**Dynamics of Compressible Flow**
ME 653	**Supersonic Aerodynamics**
ME 654	**Dynamics of Viscous Fluids**
ME 660	**Aero-Mechanical Engineering Problems**
MIM 651, MIM 652	**Theory and Structure of Metals**

DEPARTMENT OF ENTOMOLOGY

Graduate Faculty

Professors: Clyde Fuhriman Smith, *Head,* Charles H. Brett, Frank Edwin Guthrie, Robert Lamar Rabb, David Allen Young, Jr.
Professor Emeritus: Theodore Bertis Mitchell
Visiting Professor: Wesley Gordon Bruce
Associate Professors: William V. Campbell, Maurice H. Farrier, Ernest Hodgson, Alexander Russell Main, Walter Joseph Mistric, Jr., Herbert H. Neunzig
Assistant Professors: Richard Charles Axtell, Walter Carl Dauterman

The Department of Entomology offers graduate work leading to the Master of Science and Doctor of Philosophy degrees. The work in entomology is well supported by strong departments in chemistry, statistics, and the biological and plant and animal sciences.

Excellent facilities for advanced study and research are provided in a modern building designed for the use of the biological sciences. Equipment includes modern greenhouses, air-conditioned laboratories with precision temperature and humidity control, spray chambers, dust towers, low temperature rooms, and pesticide residue laboratories. Facilities are provided to support research in insect toxicology, insect physiology, insect biochemistry, biology, ecology, and taxonomy.

The well-trained faculty teaches the specialized courses in the various phases of advanced entomological work.

Opportunities for employment of well-trained entomologists are plentiful and varied. Research and teaching opportunities exist in many State institutions. Federal agencies offer positions in control, research, and regulatory work. Private industry is using more and more entomologists in the development, production, control testing and sale of agricultural chemicals. Jobs as consultants in domestic or foreign service as well as in private business and sales are available. Also, a person can go into business for himself as a pest control operator or as an insecticide formulator.

Courses for Advanced Undergraduates

ENT 401. Literature of Biology **1-0**
Prerequisite: Enrollment as upper-classman, undergraduate, or graduate
A general course intended to acquaint students with literature problems of the scientist, mechanics of the library book classifications, bibliographies, abstract journals, taxonomic indexes, and preparation of scientific papers in agriculture, forestry, biology and their sub-divisions.

Courses for Graduates and Advanced Undergraduates

ENT 502. Fundamentals of Entomology A **5-0**
Prerequisites: Twelve Hours of Biology; ENT 301 or ENT 312 or Equivalent
An intensive treatment of the general external morphology of insects and a survey of the adults and immatures of the orders and principal families of insects with attention to their biology. Messrs. Neunzig, Rabb, Young.

ENT 503. Fundamentals of Entomology B **0-5**
Prerequisites: Twelve Hours of Biology; Nine Hours of Chemistry; ENT 301 or Equivalent
Structure and morphological variations of organ systems in insects including considerations of their histology and function. Sensory physiology and behavior will then lead into the basic elements of insect ecology.
Messrs. Campbell, Hodgson, Rabb, Young.

ENT 504. Insect Morphology **3-0**
Prerequisite: ENT 502
Concerned with external morphology, primary and comparative phases, with emphasis on knowledge and techniques which can be applied to specific problems. (Offered 1963-64 and fall of alternate years.) Mr. Young.

ENT 511. Systematic Entomology **3-0**
Prerequisite: ENT 301 or ENT 312 or Equivalent
A somewhat detailed survey of the orders and families of insects, designed to acquaint the student with those groups and develop in the student some ability in the use of keys, descriptions, etc. (Offered 1964-65 and fall of alternate years.) Mr. Young.

ENT 531. Insect Ecology **3-0**
Prerequisite: ENT 301 or ENT 312 or Equivalent
The environmental relations of insects, including insect development, habits, distribution and abundance. (Offered 1963-64 and fall of alternate years.) Mr. Rabb.

ENT 541. Immature Insects **2-0**
Prerequisite: ENT 502 or Permission of Instructor
An advanced study of the immature stages of selected orders of insects with emphasis on generic and specific taxa. Primary consideration is given to the larval stage, but a brief treatment of eggs and pupae is also included. (Offered 1964-65 and fall of alternate years.) Messrs. Neunzig, Rabb.

ENT 551. Fundamentals of Insect Control **3-0**
Prerequisites: ENT 312 or Equivalent; Twelve Hours of Chemistry; Twelve Hours of Biology
The course is divided into two phases. The first deals with the basic causes of insect problems, an evaluation of the biological and economic aspects of insect attack, and the fundamental methods employed in insect control. The second part deals with the critical chemical, physical, and biological properties of compounds used for insect control. The material presented in the course is directed toward obtaining fundamental knowledge of the scientific principles underlying modern methods of protection of food, clothing, shelter, and health from anthropods. Mr. Guthrie.

ENT 552. Applied Entomology **0-3**
Prerequisites: ENT 502, ENT 503, ENT 551
A course dealing with the organization of the field of applied entomology, the significance of other disciplines, research and extension methods, the concept of integrated control, and the solution of economic problems. (Offered 1963-64 and spring of alternate years.) Mr. Mistric.

ENT 572. Forest Entomology **0-3**
Prerequisite: ENT 301 or ENT 312
A study of the methods of identification of forest pests, the factors governing their abundance, habits and control. (Offered 1964-65 and spring of alternate years.) Mr. Farrier.

ENT 582. (ZO 582) Medical and Veterinary Entomology **0-3**
Prerequisite: ENT 301 or ENT 312
A study of the morphology, biology and control of the parasitic anthropods of man, domestic and wild animals. (Offered 1963-64 and spring of alternate years.) Messrs. Farrier, Harkema.

ENT 590. Special Problems **Credits By Arrangement**
Prerequisites: Graduate Standing and Consent of the Instructor
Original research on special problems in entomology not related to a thesis problem, but designed to provide experience and training in research.
Graduate Staff.

ENT 592. Acarology **0-3**
Prerequisite: ENT 301 or ENT 312 or ZO 103
A systematic survey of the mites and ticks with emphasis on identification, biology and control of the more common and economic forms attacking material, plants and animals including man. (Offered 1964-65 and spring of alternate years.) Mr. Farrier.

Courses for Graduates Only

ENT 602. Principles of Taxonomy **0-3**
Prerequisite: ENT 511
A course introducing the methods and tools used in animal taxonomy, designed to promote a better understanding of taxonomic literature, and provide a foundation for taxonomic research. (Offered 1964-65 and spring of alternate years.) Mr. Young.

ENT 611. Biochemistry of Insects **3-0**
Prerequisite: CH 551 or Permission of Instructor
The biochemistry of insects will be considered with primary emphasis on intermediate metabolism. Aspects in which insects show specialization will be treated in greater detail. The comparative treatment used necessitates some consideration of other animal groups. (Offered 1964-65 and fall of alternate years.) Mr. Hodgson.

ENT 622. Insect Toxicology **0-3**
Prerequisites: ENT 551, CH 551 or Equivalent
The relation of chemical structure to insect toxicity, the mode of action of toxicants used to kill insects, the metabolism of insecticides in plant and animal systems, the selectivity within the cholinesterase inhibitors and other selective mechanisms, and the analysis of insecticide residues will be discussed. (Offered 1965-66 and spring of alternate years.)
Messrs. Dauterman, Guthrie.

ENT 690. Seminar **1-1**
Prerequisite: Graduate Standing in Entomology or Closely Allied Fields
Discussion of entomological topics selected and assigned by Seminar Chairman. Graduate Staff.

ENT 699. Research **Credits By Arrangement**
Prerequisite: Graduate Standing in Entomology or Closely Allied Fields
Original research in connection with thesis problem in entomology.
Graduate Staff.

DEPARTMENT OF EXPERIMENTAL STATISTICS

Graduate Faculty

Professors: David Dickenson Mason, *Head,* Richard Loree Anderson, *Graduate Administrator,* Columbus Clark Cockerham, Arnold Herbert Edward Grandage, Robert John Hader, Don William Hayne, Henry Laurence Lucas, Jr., Francis Edward McVay, Robert James Monroe, Jackson Ashcraft Rigney, Ralph Winston Stacy, Robert Douglas Steel, Hubertus Robert van der Vaart, Oscar Wesler
Professor Emeritus: Gertrude Mary Cox
Adjunct Professors: William Stokes Connor, Alva Leroy Finkler, Walter Anton Hendricks, Daniel Goodman Horvitz
Associate Professors: William Jackson Hall, Roger Gene Petersen, Charles Harry Proctor, John Oren Rawlings, William Wesley Garry Smart, Jr., Thomas Dudley Wallace
Visiting Associate Professor: John Clement Koop
Adjunct Associate Professor: William Alexander Glenn
Assistant Professors: Bibhuti Bhushan Bhattacharyya, Laurence Jay Herbst
Adjunct Assistant Professor: Sidney Addelman

The Department of Experimental Statistics offers work leading to the Master of Science, Master of Experimental Statistics (non-thesis), and Doctor of Philosophy degrees. This department has a working arrangement with the Department of Biostatistics in the University of North Carolina's School of Public Health at Chapel Hill, whereby the graduate students can major in experimental statistics and minor in the Division of Health Affairs. The Department of Experimental Statistics maintains a close liaison with the Department of (Mathematical) Statistics at Chapel Hill in order to strengthen the offerings in statistical theory. (See University of North Carolina courses listed below.) Introductory courses in the three departments are coordinated so that it is easy for a beginning statistics graduate student to transfer from one institution of the Consolidated University to another. The three departments are affiliated with the Institute of Statistics (See page 15). Some Ph.D. theses in experimental statistics are directed by members of the graduate faculty of the two statistics departments at Chapel Hill.

Members of the department conduct research in statistical theory, techniques of design and analysis for surveys and experiments, econometrics, time series and spectral analysis and computational methods. At least one staff member consults with researchers in each of the following fields and conducts his own research on statistical problems which are encountered: the various agricultural sciences, quantitative genetics, wildlife science

(game and fish), industrial development and engineering, physical sciences, and social sciences and economics.

A graduate student who majors in experimental statistics may specialize in any one of these fields with his minor in the associated department; or with a strong mathematical background he may prefer to minor in mathematics or mathematical statistics. For the graduate student who wishes to minor in statistics, the department has developed a curriculum tailored to his needs. Many employers are offering added inducements for research personnel who have such a minor. The department cooperates with other graduate departments in order to provide the type of courses needed for their students and to provide a staff to participate in their graduate programs.

A program of training in biomathematics at the doctoral and postdoctoral levels recently has been initiated in the Department of Experimental Statistics. This program requires that the student become well-grounded in four areas—mathematics, statistics, physical science, and some phase of biology. Several assistantships are available for doctoral students and several fellowships for post-doctorals. Mathematical biology and related areas are now developing rapidly and there is much opportunity for properly trained people.

In addition to its consulting services, the department provides computer programming and other assistance to the Agricultural Experiment Station staff in close cooperation with the campus Computing Center. This work is currently augmented by a computer facility grant from the National Institutes of Health. The department also provides a desk calculator computing service for sets of data not economical to program for the digital computer. It furnishes several federal agencies, other states and private concerns with research and consulting services on a contract basis. This work supplies live problems on which graduate students may acquire experience and maturity.

The Department of Experimental Statistics is located in a new building convenient to classroom and central library facilities. Ample space for graduate students is provided adjacent to faculty offices. A well-equipped desk computing laboratory is conveniently located in the graduate student area. Plans have been made for a departmental library facility, which, together with reprint files of several faculty members, will provide even easier access to the main periodicals and reference books.

The Computing Center currently has an IBM 1410 digital computer with adequate peripheral equipment. The department has, jointly with the Department of Agricultural Economics, an IBM 1620 computer. Both of the computers are available for use in connection with computer programming courses and graduate student research problems.

The department has approximately twenty graduate assistantships at stipends adjusted to the previous training and experience of the recipients. Students who have a major in an applied field and who have a minimum of one year of calculus, or students who have a major in statistics or mathematics are encouraged to apply for these assistantships. Students who have no advanced calculus or matrix algebra are advised to make arrangements to take these courses in the summer previous to entrance in the graduate program. If a graduate assistant has a satisfactory course record, he can

complete the requirements for the master's degree in two years (in less time if he takes courses during the summer). A graduate assistant with a master's degree in statistics can complete the requirements for the doctorate in two years.

Most fields of research, development, production, and distribution are seeking persons trained in statistical theory and methods. The demand is equally strong from universities, agricultural and engineering experimental stations, national defense agencies, other federal agencies, and a wide variety of industrial concerns. There is a need for experimental statisticians with the master's degree as well as for those with the doctorate.

At the request of the Southern Regional Education Board's Advisory Commission on Statistics, Virginia Polytechnic Institute, Oklahoma State University, the University of Florida, and North Carolina State have joined in a continuing program of graduate summer sessions in statistics, held at the four institutions in rotation. In 1964, the host institution is the Virginia Polytechnic Institute, followed by the University of Florida and Oklahoma State Unversity. Each of the sponsoring institutions will accept the credits earned by students in the summer sessions as residence credit. The courses are arranged to provide consecutive work in successive summers. Information regarding these courses may be obtained from any of the cooperating statistical departments or the deans of the Graduate Schools.

Courses for Advanced Undergraduates

ST 421, ST 422. Introduction to Mathematical Statistics **3-3**
Prerequisite: MA 202 or MA 212
Elementary mathematical statistics primarily for students not intending to take further work in theoretical statistics. Includes introduction to probability, common theoretical distributions, moments, moment generating functions, sampling distributions, (F, t, chi-square), elementary estimation and hypothesis testing concepts, bivariate distributions, simple and multiple linear regression, analysis of variance, and elementary design of experiments.

Courses for Graduates and Advanced Undergraduates

ST 501, ST 502. Basic Statistical Analysis **3-3**
Prerequisite: ST 311 or Equivalent or Graduate Standing
Basic concepts of statistics; random variables, distributions, statistical measures, estimation, tests of significance, analysis of variance, elementary design and sampling, factorial experiments, multiple regression, analysis of discrete data, and other topics. Intended primarily for statistics majors and Ph.D. minors and not intended as a service course for other departments.
Mr. Steel.

ST 511. Experimental Statistics for Biological Sciences I **3-3**
Prerequisite: ST 311 or Graduate Standing
Basic concepts of statistical models and use of samples; variation, statistical measures, distributions, tests of significance, analysis of variance and elemen-

tary experimental design, regression and correlation, chi-square. [Offered also in special summer sessions at Virginia Polytechnic Institute (1964) and University of Florida (1965).] Messrs. Monroe, Rawlings.

ST 512. Experimental Statistics for Biological Sciences II **3-3**
Prerequisite: ST 511 or Equivalent
Convariance, multiple regression, factorial experiments, individual degrees of freedom, incomplete block designs, experiments repeated over space and time. [Offered also in special summer session at Virginia Polytechnic Institute (1964) and University of Florida (1965).] Messrs. Mason, Monroe.

ST 513. Experimental Statistics for Social Sciences I **3-0**
Prerequisite: ST 311 or Graduate Standing
Basic concepts in collection and analysis of data. Variability of sample data, distributions, confidence limits, chi-square, t-test, analysis of variance, regression, correlation, experimental designs. Mr. McVay.

ST 514. Experimental Statistics for Social Sciences II **0-3**
Prerequisite: ST 513 or Equivalent
Extension of basic statistical concepts to social experiments and surveys; sampling from finite populations and estimating using unrestricted, stratified, systematic, and multistage selections; analysis of variance continued; multiple regression; covariance; experimental designs. Mr. Proctor.

ST 515, ST 516. Experimental Statistics for Engineers **3-3**
Prerequisite: ST 361 or Graduate Standing
General statistical concepts and techniques useful to research workers in engineering, textiles, wood technology, etc. Probability, distributions, measurement of precision, simple and multiple regression, tests of significance, analysis of variance, enumeration data, sensitivity data, and experimental design. (Offered also in regular summer session.) Mr. Hader.

ST 531. (BS 531) Biomathematics I **3-0**
Prerequisites: MA 301, MA 405, or Consent of Instructor
Linear time-invariant operators and their Laplace transforms, with a discussion of homogeneous and non-homogeneous linear differential equations and their analysis in time-domain and frequency-domain; applications to the study of input and output in biological systems; systems of linear and non-linear differential equations and their perturbation equations, especially with reference to the study of population dynamics and growth processes, stability of biological systems, and tracer kinetics. Mr. van der Vaart.

ST 532. (BS 532) Biomathematics II **0-3**
Prerequisites: ST 531, ST 541 (MA 541), or Consent of Instructor
Continuation of topics in ST 531. The general framework for mathematization of biological problems; deterministic and stochastic models; birth and death processes with applications to physiology and population dynamics; desirable features of mathematical models in biology.
Mr. van der Vaart.

ST 541. (See MA 541. Theory of Probability I.)

ST 542. (See MA 542. Theory of Probability II.)

ST 551. Basic Statistical Inference **0-3**
Prerequisites: MA 441, ST 541 (MA 541)
Frequency distributions and moments; sampling distributions; introductory theory of point and interval estimation; tests of hypotheses. [Offered also in special summer sessions at Virginia Polytechnic Institute (1964) and University of Florida (1965).] Mr. Grandage.

ST 552. Basic Theory of Least Squares and Variance Components **3-0**
Prerequisites: ST 551, MA 405
Theory of least squares; multiple regression; analysis of variance and covariance; experimental design models; factorial experiments; variance component models. [Offered also in special summer sessions at Virginia Polytechnic Institute (1964) and University of Florida (1965).]
Mr. Anderson.

ST 591. Special Problems **1 to 3 - 1 to 3**
Development of techniques for specialized cases, particularly in connection with thesis and practical consulting problems. Graduate Staff.

U.N.C. ST 111. Methods of Mathematical Statistics I **3-0**
Prerequisite: Advanced Calculus
Introductory treatment of special mathematical techniques of particular importance in probability and statistics, including topics from combinatorial mathematics, Fourier and Laplace transforms, contour integration, special inequalities and finite differences. Mr. Smith.

U.N.C. ST 131. Elementary Probability Theory **3-0**
Prerequisite: Advanced Calculus
Fundamentals of probability theory and distribution theory essential for the study of mathematical statistics, including: axiomatic treatment of probability models, combinatorial probability, conditional probability and independence, random variables, distribution and density functions, moments and generating functions, combined random variables.
Messrs. Hall, Johnson.

U.N.C. ST 132. Intermediate Probability **0-3**
Prerequisite: U.N.C. ST 131 or ST 134
Laws of large numbers, characteristic functions, and central limit theorems. Elements of stochastic processes and their applications, including random walks, Markov chains, recurrent events, Brownian motion, and elementary queueing theory. Mr. Smith.

U.N.C. ST 133. Least Squares and Times Series **3-0**
Prerequisites: U.N.C. ST 134; Matrix Algebra
The classical method of least squares with modern improvements and developments. Interpretations of the results in terms of probability. Applications to social and to natural sciences. The problem of observations ordered in time. Correlation and regression of time series. Seasonal variation and secular trends. Methods of correcting for lack of independence and of avoiding fallacies. Mr. Hotelling.

U.N.C. ST 134. Statistical Theory I **5-0**
Prerequisite: Advanced Calculus
U.N.C. ST 131 plus regression and correlation theory, convergence and approximation, common distributions, functions of random samples, multinormal theory, and random normal sampling. Messrs. Hall, Johnson.

U.N.C. ST 135. Statistical Theory II **0-3**
Prerequisite: U.N.C. ST 131 or ST 134
Fundamentals of statistical inference and statistical decision theory, including: the decision and inference problem, sufficient statistics, point estimation (unbiasedness, Bayes and minimax methods, maximum likelihood and large sample theory), hypothesis testing, interval estimation, chi-square tests, and introduction to nonparametric, Bayesian, and sequential methods. Linear estimation, analysis of variance and regression are largely excluded.
Messrs. Hall, Johnson.

U.N.C. ST 144. Correlation, Contingency, and Chi Tests
Prerequisite: U.N.C. ST 135
Corequisite: Matrix Algebra
Elements of the theory of testing composite hypotheses. Multivariate normal populations; total, partial, and multiple correlations. Singular multivariate distributions. Tests of independence, homogeneity, and goodness-of-fit. Contingency tables; exact tests for independence and the chi approximation. Many-dimensional contingency tests. Mr. Hotelling.

U.N.C. ST 150. Analysis of Variance with Application to Experimental Designs **0-3**
Corequisite: U.N.C. ST 135
Linear estimation. Non-estimability. The best linear estimate and its variance. The Gauss-Markov theorem. Sums of squares. Analysis of variance and the generalized t and F tests. Unified mathematical theory of the intrablock analysis of incomplete block designs. Applications to balanced, lattice, partially balanced and Latin square designs. Mr. Bose.

U.N.C. ST 182 Mathematical Economics **3-0**
Prerequisite: Advanced Calculus
Corequisite: Matrix Algebra
Perfect and imperfect competition. Monopoly. Utility vs. ranking of preferences. Relations between commodities. General equilibrium. Effects of taxes and controls of various kinds. Index numbers. Welfare economics. (Offered in fall of 1964-1965 and alternate years.) Mr. Hotelling.

U.N.C. ST 183. Advanced Mathematical Economics **0-3**
Prerequisites: U.N.C. ST 182, Differential Equations
Dynamic variations in the economy. Calculus of variations and stochastic process theory with applications to economic problems. Valuation, depreciation, and depletion. Most profitable rates of exploitation of mineral and biological resources. (Offered in spring of 1964-1965 and alternate years.)
Mr. Hotelling.

U.N.C. ST 197. Population Statistics **0-3**
Prerequisite: Permission of Instructor
Training in techniques for quantitative research with population data, composition characteristics, making of population estimates, computation and standardization of birth and death rates, construction and application of life tables, measurement of migration. Mr. Price.

Courses for Graduates Only

ST 611, ST 612. Intermediate Statistical Theory **3-3**
Prerequisites: ST 551, MA 512, MA 405
This course will provide the additional theory, above that of ST 551, needed for many advanced theory courses. Many of the topics of ST 551 will be developed more rigorously, with more attention paid to mathematical aspects. Advanced probability theory; limit theorems, distribution theory, multinormal distributions. Statistical decision theory, theory of estimation, confidence regions, theory of tests of hypotheses, sequential tests, non-parametric methods. Mr. Bhattacharyya.

ST 613. Time Series Analysis I **0-3**
Prerequisite: ST 552
Statistical analysis of realizations of second order stationary random processes, and mathematical specifications of the underlying processes, with emphasis throughout on the spectrum. Discussions of applications are given to illustrate the theory and methods. Topics include second order stationary parent sequences, correlation analysis, autoregressive series, moving averages, hidden periodicities models, spectral analysis, estimation of the correlogram and the coefficients of autoregressive schemes, the periodogram, estimation of the spectral density; serial correlation theory, goodness-of-fit tests.
Mr. Herbst.

ST 614. Time Series Analysis II **3-0**
Prerequisites: ST 613, ST 542 (MA 542)
Cross-covariance analysis of two time series, cross-spectral analysis of two time series, estimation of co-spectral density, quadrature-spectral density, coherence and phase, interpretations and applications of coherence analysis, detection and estimation of periodicities in variances of time series, spectral representation theory for second order stationary processes, further discussion of spectral estimation. Mr. Herbst.

ST 621. Statistics in Animal Science **3-0**
Prerequisite: ST 502 or Equivalent
Sources and magnitude of errors in experiments with animals, experimental designs and methods of analysis adapted to specific types of animal research, relative efficiency of alternate designs, amount of data required for specified accuracy, student reports on selected topics. (Offered in fall of 1965-1966 and alternate years.) Mr. Lucas.

ST 622. (See ANS 622. Principles of Biological Assays.)

ST 623. Statistics in Plant Science **3-0**
Prerequisite: ST 502 or Equivalent
Principles and techniques of planning, establishing, and executing field and greenhouse experiments. Size, shape and orientation of plots; border effects; selection of experimental material; estimation of size of experiments for specified accuracy; scoring and subjective tests; subsampling plots and yields for laboratory analysis. Mr. Mason.

ST 626. (GN 626) Statistical Concepts in Genetics **0-3**
Prerequisite: GN 512
Corequisite: ST 502 or Equivalent
Factors bearing on rates of change in population means and variances, with

special reference to cultivated plants and domestic animals; selection, inbreeding, magnitude and nature of genotypic and non-genotypic variability; experimental and statistical approaches in the analysis of quantitative inheritance. Mr. Cockerham.

ST 631. Theory of Sampling Applied to Survey Design **3-0**
Prerequisite: ST 422 or ST 502 or Equivalent
Basic theory of sampling from a finite population. Confidence limits and estimation of optimum sample size, comparison of different sample designs, methods and probabilities for selection and methods of estimation, choice of a sampling unit, double sampling, matched samples. Mr. Proctor.

ST 641. (See RS 641. Statistics in Sociology.)

ST 651. (See AGC 651. Econometric Methods I.)

ST 652. (AGC 652) Econometric Methods II **0-3**
Prerequisites: ST 422 or ST 552, MA 405
Mathematical programming, theory of games. Applications of dynamic programming techniques and queueing theory to problems of inventory and replacement. Special topics in regression analysis.
Messrs. Anderson, Bhattacharyya.

ST 671. Advanced Topics in Least Squares and Variance Components **0-3**
Prerequisites: ST 502 or Equivalent, ST 552
Use of non-balanced designs to estimate variance components; comparison of estimators; problems with finite populations. Least squares procedures for non-standard conditions; unequal variances, correlated errors, non-additivity, measurement errors, non-normality. Functional relationships. Factorial experiments with continuous factor levels; incomplete blocks.
Mr. Anderson.

ST 672. Special Advanced Topics in Statistical Analysis **3-0**
Prerequisites: ST 502 or Equivalent, ST 552
Enumeration data; covariance; non-linear models; discriminant functions and other multivariate techniques. Mr. Monroe.

ST 674. Advanced Topics in Construction and Analysis of Experimental Designs **0-3**
Prerequisites: ST 502 or Equivalent, ST 552
Interblock analysis of incomplete blocks designs, partially balanced designs, confounding, data collected at several places and times, multiple factor designs, change-over trails, analysis of groups of means. Mr. Addelman.

ST 691. Advanced Special Problems **1 to 3 - 1 to 3**
Prerequisites: ST 502 or Equivalent, ST 552
Any new advance in the field of statistics which can be presented in lecture series as unique opportunities arise, including (a) theory of sampling applied to survey design and (b) analysis of linear models.
Graduate Faculty, Visiting Professors.

ST 694. Seminar **1-1**
A maximum of two credits is allowed toward the master's degree, but any number toward the doctorate. Graduate Staff.

ST 699. Research **Credits by Arrangement**
A maximum of nine credits is allowed toward the Master of Science degree; no limitation on credits in doctorate programs. Graduate Staff.

U.N.C. ST 200. Applied Multivariate Analysis I **3-0**
Prerequisite: U.N.C. ST 135
Relations between multiple regression, analysis of variance, multivariate analysis and factor analysis. Tests with discriminant functions. The generalized Student ratio. Use of roots of determinantal equations. Classification problems. Distance and group constellations. (Offered in fall of 1964-1965 and alternate years.) Mr. Nicholson.

U.N.C. ST 202. Methods of Operations Research **3-0**
Prerequisite: U.N.C. ST 135
Linear programming, theory of games, techniques for analyzing waiting lines and queues. Applied probability, recent developments, applications of results to specific problems. Case studies. Messrs. Nicholson, Smith.

U.N.C. ST 204. Selected Techniques of Approximation **3-0**
Prerequisite: Advanced Calculus
The methods of steepest descent and other methods of approximating integrals, with special attention to integrals occurring in probability and statistics. Asymptotic series. Large-sample approximations. Orthogonal polynomials and their applications to numerical quadrature, interpolation and moment problems. (Offered in fall of 1965-1966 and alternate years.)
Mr. Hotelling.

U.N.C. ST 212. Methods of Mathematical Statistics II **0-3**
Prerequisite: Advanced Calculus
Measure and integration theory, with special reference to random variables, distribution functions, probability measures, and including Fubini's Theorem, the Radon-Nikodym Theorem, conditional probability, conditional expectation, and modes of convergence. Messrs. Hall, Smith.

U.N.C. ST 220. Theory of Estimation and Hypothesis Testing **4-0**
Prerequisites: U.N.C. ST 132, ST 135, ST 212
Bayes procedures for estimation and testing. Minimax procedures. Sufficient statistics. Optimal unbiased estimators. Most powerful similar tests. Admissibility. Invariance. Confidence sets. Large sample theory.
Messrs. Hall, Hoeffding.

U.N.C. ST 221. Sequential Analysis **2-0**
Prerequisites: U.N.C. ST 132, ST 135
Hypothesis testing and estimation when the sample size depends on the observations. Sequential probability ratio tests. Sequential design of experiments. Stochastic approximation. Mr. Hoeffding.

U.N.C. ST 222. Nonparametric Inference **0-3**
Prerequisites: U.N.C. ST 132, ST 135, ST 212
Estimation and testing when the functional form of the population distribution is unknown. Rank and sign tests. Tests based on permutations of observations. Power of nonparametric tests. Optimum nonparametric tests and estimators. Nonparametric confidence intervals and tolerance limits.
Mr. Hoeffding.

U.N.C. ST 231. Advanced Probability **3-0**
Prerequisites: U.N.C. ST 132, ST 212
Advanced theoretic course, including: random variables and expectations,

distributions and characteristic functions, infinitely divisible distributions, central limit theorems, laws of large numbers, and stable laws. (Offered in fall of 1964-1965 and alternate years.) Mr. Smith.

U.N.C. ST 232. General Theory of Statistical Decision **0-3**
Prerequisites: U.N.C. ST 135, ST 212
Selected topics in the general theory of statistical decisions, based on the work of Abraham Wald. (Offered in spring of 1964-1965 and alternate years.) Mr. Hoeffding.

U.N.C. ST 235. Stochastic Processes **0-3**
Prerequisites: U.N.C. ST 132, ST 212
Advanced theoretic course, including: separability of a process, processes with orthogonal random variables, Markov processes, martingales, and processes with independent increments. (Offered in spring of 1965-1966 and alternate years.) Mr. Smith.

U.N.C. ST 237. Time Series Analysis **0-3**
Prerequisite: U.N.C. ST 133
Analysis of data involving trends, seasonal variations, cycles and serial correlations. Periodograms and correlograms. Exogenous and endogenous cycles. Stochastic difference equations. Tests for randomness. Distributions of serial correlation coefficients. The sinusoidal limit theorem. (Offered in spring of 1965-1966 and alternate years.) Mr. Hotelling.

U.N.C. ST 251. Combinatorial Problems of the Design of Experiments **3-0**
Prerequisite: U.N.C. ST 150
Application of Galois fields and two dimensional finite geometries to the construction of complete sets of orthogonal Latin squares. Finite hyperspace geometries and balanced incomplete block designs obtainable from them. Factorial designs. Theory of confounding. Construction and analysis of symmetrical factorial designs with confounding. Construction and analysis of symmetrical fractionally replicated designs. Mr. Bose.

U.N.C. ST 252. Information Theory **3-0**
Prerequisite: U.N.C. ST 132
Corequisite: U.N.C. ST 212
Transmission of information. Entropy. Simple message ensembles. Discrete sources. Transmission channels. Channel encoding and decoding. Encoding for binary symmetric channels. Encoding for discrete constant channels. (Offered in fall of 1965-1966 and alternate years.) Mr. Bose.

U.N.C. ST 253. Error Correcting Codes **0-3**
Prerequisite: U.N.C. ST 251
Linear codes and their error correction capabilities. Some important linear codes. Linear switching circuits. Cyclic codes, Bose-Chaudhuri codes. Codes for burst error correction. Recurrent codes. Codes for checking arithmetic operations. (Offered in spring of 1965-1966 and alternate years.) Mr. Bose.

U.N.C. ST 254. Special Topics in Design of Experiments I **3-0**
Prerequisite: U.N.C. ST 150
Response surface designs. Conditions for rotatibility. Construction and analysis of rotatable designs of the second and third order. Interblock

analysis. General analysis of covariance. Missing plot techniques. (Offered in fall of 1964-1965 and alternate years.) Mr. Bose.

U.N.C. ST 255. Special Topics in the Design of Experiments II 0-3
Prerequisite: U.N.C. ST 251
Combinatorial properties and construction of balanced, group divisible and partially balanced designs. Impossibility proofs. Orthogonal Latin squares of non-prime power orders. Orthogonal arrays. Asymmetrical fractionally replicated designs. (Offered in spring of 1964-1965 and alternate years.) Mr. Bose.

U.N.C. ST 260. Multivariate Analysis 3-0
Prerequisites: U.N.C. ST 135, Matrices
Characterization and properties of a multivariate normal distribution, random samples from this distribution. Tests and confidence intervals related to the hypotheses of equality of two or more dispersion matrices against various types of alternatives. Multivariate analysis of variance, covariance and regression, under a linear model with fixed effects against various types of alternatives, and associated tests and confidence bounds. Association between subsets of a multivariate normal set, including several kinds of independence. Factor analysis. Mr. Roy.

U.N.C. ST 261. Advanced Multivariate Analysis 0-3
Prerequisite: U.N.C. ST 260
Distribution problems connected with the tests and confidence intervals discussed in U.N.C. ST 260. The properties, in terms of statistical inference, of the tests and confidence intervals against different classes of alternatives. Advanced multivariate analysis of variance under a linear model with random or mixed-type effects against various kinds of alternatives. Multivariate designs for problems of MANOVA and for patterned dispersion matrices. Problems of classification. Some applications. Mr. Roy.

U.N.C. ST 262. Multifactor Multiresponse Experiments with Response Not Necessarily Normal 3-0
Corequisite: U.N.C. ST 260
Unstructured and structured factors. Unstructured and structured responses based on a single or a product multinominal or hypergeometric distribution. Hypotheses against alternatives, analogous to those discussed in U.N.C. ST 260 for the multivariate normal case. Large sample tests and the associated confidence intervals. One or more structured responses based on a continuous c.d.f., and the appropriate hypotheses against alternatives in this situation. Exact and asymptotic tests. Mr. Roy.

U.N.C. ST 263. Advanced Multifactor Multiresponse Experiments with Responses Not Necessarily Normal 0-3
Prerequisite: U.N.C. ST 262
Properties, in terms of statistical inference, of the tests and confidence intervals discussed in U.N.C. ST 262. Generalization of univariate or multivariate analysis of variance to the case of normal error and random effects not necessarily normal. Design and analysis of factorial experiments with one or more normal response-types, treated as a problem in structured hypothesis. Relation to the classical design and analysis of factorial experiments and to those based on the response surface approach. Mr. Roy.

U.N.C. ST 300-301. Seminar in Statistical Literature **1-1**
Prerequisite: U.N.C. ST 135

Graduate Staff.

U.N.C. ST 310-311. Seminar in Theoretical Statistics **3-3**
Prerequisite: U.N.C. ST 135

Graduate Staff.

U.N.C. ST 321-322. Special Problems **3-3**
Prerequisite: Permission of the Instructor

Graduate Staff.

U.N.C. ST 331-332. Advanced Research **3-3**
Prerequisite: Permission of the Instructor

Graduate Staff.

DEPARTMENT OF FOOD SCIENCE

Graduate Faculty

Professors: William Milner Roberts, *Head,* Leonard William Aurand, Thomas Nelson Blumer, John Lincoln Etchells, Maurice W. Hoover, Ivan Dunlavy Jones, Marvin Luther Speck, Frederick Gail Warren
Associate Professors: Thomas Alexander Bell, Daniel Fromm, Fred Russell Tarver, Jr.

The Department of Food Science was established at North Carolina State in 1961 to integrate the various scientific disciplines which are basic to the preparation, processing, packaging, and distribution of foods in general. Programs of graduate study are offered leading to the Master of Science and Doctor of Philosophy degrees. In order to pursue graduate study in the field of food science, the student must possess adequate information in the fundamentals of the area in which he expects to specialize. The student's undergraduate education should have prepared him in mathematics, chemistry, biological and physical sciences as well as in the humanities and language skills. Following this preparation, the student can pursue more specialized fields.

In the area of food chemistry, the student can conduct research and study in peroxidation of lipids in foods, flavor chemistry, protein denaturation, and various problems of biophysical chemistry.

Engineering aspects of food science are offered in the principles of automation and industrial engineering in food plant operations.

The field of food products technology is concerned with the development of new foods and the improved quality of existing foods.

Food microbiology is designed to offer study and research in fundamental principles of microbiology involved in promoting growth of microorganisms essential to the manufacture of various foods and the control of unwanted microorganisms in foods.

The department's physical facilities include research laboratories equipped for chemistry and microbiology, and processing facilities and equipment for dairy, fruit, vegetable, poultry, and meat products.

The Department of Food Science maintains close liaison with the facul-

ties of supporting departments. Depending on the area chosen by the student for his major interest, he will have strong support for his minor from faculties in chemistry, economics, engineering, genetics, microbiology, and statistics.

A graduate program in Food Science and Sanitation is offered by the Department of Food Science and the Department of Environmental Sciences and Engineering of the University of North Carolina at Chapel Hill. This program is designed to provide an enrichment in environmental health to graduate students majoring in Food Science at Raleigh; similarly, it is to provide an enrichment in food science to graduate students majoring in Environmental Sciences and Engineering at Chapel Hill.

Courses for Advanced Undergraduates

FS 401. Market Milk and Related Products **3-0**
Principles of processing, distribution and quality of fluid milk and related products.

FS 403. Ice Cream and Related Frozen Dairy Foods **0-3**
Prerequisite: FS 401
Choice, preparation and processing of ingredients and freezing of ice cream and other frozen desserts.

FS 404. (PO 404) Poultry Products **3-0**
Prerequisites: CH 101, ZO 103
Selection, processing, grading and packaging poultry meat and eggs. Factors involved in preservation of poultry meat and eggs.

FS 410. Food Products Evaluation **0-3**
Prerequisite: ST 361 or Equivalent
A comprehensive study of problems encountered in new food product development and consumer acceptance. A study of the nature of sensory responses with emphasis on taste, smell and appearance (color) as related to foods; design and methodology of small and large consumer panel testing; and the application of appropriate mathematical procedures to food acceptance testing and methodology.

Courses for Graduates and Advanced Undergraduates

FS 502. Food Chemistry **3-0**
Prerequisite: CH 220 or CH 221
The basic composition, structure and properties of food, and the chemistry of changes occurring during processing and utilization of food. Interpretation and integration of widely published data in the food field with basic principles of chemistry. Mr. Aurand.

FS 503. Food Analysis **0-3**
Prerequisites: CH 215, CH 351, FS 502
A study of the principles, methods and techniques necessary for quantitative physical and chemical analyses of food and food products. Results of analysis will be studied and evaluated in terms of quality standards and governing regulations. Mr. Aurand.

FS 505. (BO 505) Food Microbiology **0-3**
Prerequisite: BO 412
The relationship of habitat to the occurrence of microorganisms on foods; environmental factors affecting the growth of various microorganisms in foods; microbiological action in relation to food spoilage and food manufacture; physical, chemical and biological destruction of microorganisms in foods; methods for microbiological examination of food-stuffs; and public health and sanitation bacteriology. Mr. Speck.

FS 506. (BO 506) Advanced Food Microbiology **3-0**
Prerequisite: FS 505 or Consent of Instructor
Ecology and physiology of microorganisms important in the manufacture and deterioration of various classes of foods; the identification of representative species of such microorganisms isolated from natural environments; principles of nutrition, symbiosis and bacteriophage activity in culture maintenance for food production. Mr. Speck.

FS 521, FS 522. Technology of Fruit and Vegetable Products **3-3**
Prerequisite: BO 412
Comprehensive treatment of principles and methods of preservation of fruits and vegetables, including studies of commercial plant operations, and visits to food processing plants. Mr. Hoover.

FS 590. Food Science Seminar **0-1**
Prerequisites: Senior or Graduate Standing and Consent of Instructor
A review and discussion of scientific articles, progress reports in research and special problems of interest. Graduate Staff.

FS 591. Special Problems in Food Science **1 to 3 - 1 to 3**
Prerequisites: Senior or Graduate Standing and Consent of Instructor
Analysis of scientific, engineering and economic problems of current interest in foods. The scientific appraisal and solution of a selected problem. The problems are designed to provide training and experience in research.
Graduate Staff.

Courses for Graduates Only

FS 690. Seminar in Food Science **1-1**
Preparation and presentation of scientific papers, progress reports of research and special topics of interest in foods. Graduate Staff.

FS 691. Special Research Problems in Food Science **Credits by Arrangement**
Directed research in a specialized phase of food science designed to provide experience in research methodology and philosophy. Graduate Staff.

FS 699. Research in Food Science **Credits by Arrangement**
Original research preparatory to the thesis for the Master of Science or Doctor of Philosophy degree. Graduate Staff.

SCHOOL OF FORESTRY

Graduate Faculty

Professors: Richard Joseph Preston, *Dean*, Roy Merwin Carter, John Warren Duffield, Eric Louis Ellwood, Benjamin Anderson Jayne, Arthur Kelman, Joe Oscar Lammi, T. Ewald Maki, Alfred J. Stamm, Bruce J. Zobel

Associate Professors: Aldos Cortez Barefoot, Jr., Charles Bingham Davey, Maurice H. Farrier, Clarence Arthur Hart, Thomas O. Perry

Assistant Professors: Gene Namkoong, Leroy C. Saylor

The School of Forestry offers graduate work leading to the Master's and the Doctor of Philosophy degrees. Two types of master's programs are available to the graduate student.

The professional degrees of Master of Forestry and Master of Wood Technology are offered for students who are interested in advanced applications of fundamental principles to the specialized fields of forestry. The course program emphasizes professional specialization. There is no language requirement.

The degree of Master of Science is offered for the student who contemplates a career in research, in teaching, or both. The course of study for the Master of Science degree provides for a comprehensive knowledge of forest management or wood technology and furnishes the training essential for successful research in these fields. Training is broadly-based and emphasizes fundamental science. There is both a thesis and language requirement.

The Doctor of Philosophy degree is available to forestry students of high intellectual capactiy who can demonstrate the ability to undertake original research and scholarly work at the highest levels.

Candidates for the master's degree fall under one of the following categories:

1. Students with a bachelor's degree in forestry from a school of recognized standing. These students may secure the master's degree in one academic year.

2. Students with a bachelor's degree, other than in forestry, from a college, university, or scientific school of high standing. These students may secure the master's degree in two academic years provided they have the requirements in botany, chemistry, and mathematics required in the freshman and sophomore years of the curricula. Candidates for the degree of Master of Forestry or Master of Science in forest management who do not hold an undergraduate degree in forestry must start their program with the summer camp.

3. Students not possessing a bachelor's degree may earn, through proper selection of courses, a Bachelor of Science degree in one of the forestry curricula at the end of the fourth year and a master's degree in forestry or wood technology at the end of the fifth year.

A wide and rapidly expanding field of employment possibilities is available in the Southeast to young men trained in forestry. Until recent years most job opportunities were with government agencies in managing public forests. This field still constitutes a major source of employment. These

agencies include state and federal forest services, extension services, and other groups such as the Soil Conservation Service and the Tennessee Valley Authority.

In recent years job opportunities with private industries have expanded greatly. Increasing numbers of technically trained young men are entering a wide variety of professional positions in the fields of forest land management, watershed management, logging, sawmilling, veneer and plywood manufacturing, pulp and papermaking, kiln drying, wood preservation, plastics and other chemical derivatives of wood, and the manufacture of wood products such as furniture, dimension stock, and various prefabricated items.

Graduate training offers tangible well-established values to young men of proven ability. The demand for men with advanced degrees in forestry has far exceeded the supply for many years.

Graduate preparation is essential for the specialists which are needed in many fields. Training through the master's degree is almost a requirement for men entering college teaching and public or industrial research. State and federal agencies as well as forest industries are employing research investigators at unprecedented levels.

The continuing rapid expansion of southern forestry has resulted in a corresponding expansion in the need for trained men. As a general rule most employers will prefer a candidate with graduate training. While forest industry and public forest administration do not normally require graduate training, increasing numbers of positions in these fields are being filled by men with advanced forestry degrees, particularly the master's degree.

The administrative offices of the School of Forestry are located in Kilgore Hall. The first floor houses portions of the Wood Products Laboratory and the second and third floors consist of laboratories, library, classrooms, and offices. The Reuben B. Robertson Pulp and Paper Laboratory provides 12,000 square feet of space for teaching and research in the production of pulp and paper. The Brandon P. Hodges Wood Products Laboratory provides 18,000 square feet of space for pilot plant installations for product development work in the manufacture of lumber, veneer, plywood, particle board, laminated structures, furniture, and other fabricated wood products.

The School of Forestry now owns, or has access to, over 80,000 acres of forest land located in six tracts and representing major forest types in the State. The largest tract is the Hofmann Forest on the coastal plain which is operated by the North Carolina Forestry Foundation for the benefit of the School of Forestry. The Hill Forest in Durham County, the Hope Valley Forest in Chatham County, the Goodwin Forest in Moore County, and the Schenck Memorial Forest in Wake County include representative types of the Piedmont area. The Wayah Recreational Area of the North Carolina National Forest near Franklin is located in a typical mountain forest, and facilities at this area, leased from the Government, supplement the previously established forestry camps of the Hofmann and Hill Forests and provide the School with permanent, well-equipped, modern camps in each of the three major regions of the State.

An extensive research program in the fields of wood products, genetics and management, sponsored by the Agricultural Experiment Station, the

U. S. Forest Service, and the lumber, plywood, furniture, pulp and paper, and particle board industries provides broad opportunities for graduate research at the master's and doctoral level. These programs offer research assistantships for graduate students whose backgrounds qualify them. Much valuable equipment is made available by industry for research in wood technology and it is accessible to the graduate student working in this area.

Courses for Advanced Undergraduates

FOR 403. Paper Process Analysis **0-3**
Manufacture of several types of papers with particular attention to stock preparation, sizing, filling and coloring. The finished products are tested physically and chemically and evaluated from the standpoint of quality and in comparison with the commercial products they are intended to duplicate.

FOR 404. Management Analysis **0-3**
Application of management, logging, silvicultural and utilization practices on assigned areas. Each student must make a forest survey of an individual area and submit a report.

FOR 405. Forest Inventory **0-3**
Timber estimating and data compilation.

FOR 411, FOR 412. Pulp and Paper Unit Processes **3-3**
Principles of operation, construction and design of process equipment in the pulp and paper industry.

FOR 413. Paper Properties and Additives **4-0**
Physical, chemical and microscopical examination of experimental and commercial papers and evaluation of the results in terms of the utility of the product tested.

FOR 422. Forest Products **3-0**
Prerequisites: FOR 201; CH 203 or CH 426
The source and method of obtaining derived and manufactured forest products other than lumber.

FOR 423. Logging and Milling **3-0**
Timber harvesting and transportation methods, equipment and costs; safety and supervision; manufacturing methods; log and lumber grades.

FOR 432. Merchandising Forest Products **2-0**
Principles and practices in the distribution and marketing of the products obtained from wood; organization and operation of retail, concentration and wholesale outlets.

FOR 434. Wood Operations I **3-0**
Prerequisites: FOR 301, FOR 302
Organization of manufacturing plants producing wood products including company organization, plant layout, production planning and control. Analysis of typical manufacturing operations in terms of process, equipment, size and product specification. The organization and operation of Wood Products markets.

FOR 435. Wood Operations II **0-3**
Prerequisites: FOR 301, FOR 302
The application of the techniques of operations analysis to management decision making in the wood products field. Choice of products to manu-

facture. Allocation of production resources. Development of product distribution systems.

FOR 441. Design of Wood Structures **0-3**
Prerequisite: EM 341
Strength and related properties of commercial woods; standard A.S.T.M. strength tests; toughness; timber fastenings; design of columns; simple, laminated and box beams; trusses and arches.

FOR 444. Introduction to Quality Control **0-3**
Prerequisite. ST 361
A study of methods used to control quality of manufactured wood products. Control charts for variable and attributes. Acceptance sampling techniques.

FOR 461. Paper Converting **0-1**
A survey of the principal processes by which paper and paper board are fabricated into the utilitarian products of everyday use.

FOR 462. Artificial Forestation **0-2**
Production collection, extraction, and storage of forest tree seeds; nursery practice; field methods of planting.

FOR 463. Plant Inspections **0-1**
One week inspection trips covering representative manufactures of pulp paper and papermaking equipment.

FOR 471. Pulping Process Analysis **4-0**
Preparation and evaluation of the several types of wood pulp. The influence of the various pulping and bleaching variables on pulp quality are studied experimentally and these data evaluated critically.

FOR 481. Pulping Processes and Products **0-2**
Prerequisites: FOR 202, CH 203 or CH 221
Fiber manufacturing process and equipment; wall insulation and container board products; manufacture of roofing felts; pulp products manufacturing; resin and specialty products, lignin and wood sugar products.

FOR 482. Pulp and Paper Mill Management **0-2**
A survey of the economics of the pulp and paper industry is followed by a study of the work of the several departments of a paper mill organization and the functions of the executives who administer them.

FOR 491, FOR 492. Senior Problems **Credits by Arrangement**
Problems selected with faculty approval in the areas of management or technology.

Courses for Graduates and Advanced Undergraduates

FOR 501. Forest Valuation **3-0**
Prerequisite: FOR 372
The theory and techniques of valuation of forest land, timber stands, and forest practices as investments and for appraisals of damage. Risks and hazards in forestry as they apply to forest investments, forest insurance, and forest taxation. Mr. Bryant.

FOR 511. Silviculture **0-3**
Prerequisites: FOR 361, BO 421
The principle and application of intermediate and reproductive methods

of cutting; controlled burning, silvicides, and other methods of hardwood control. The application of silvicultural methods in the forests of the United States. Mr. Duffield.

FOR 512. Forest Economics **3-0**
Prerequisites: FOR 372, EC 201
Economics and social value of forests; supply of, and demands for forest products; land use; forestry as a private and a public enterprise; economics of the forest industries. Mr. Lammi.

FOR 513. Tropical Woods **0-2**
Prerequisites: FOR 203, FOR 301
Structure, identification, properties, characteristics and use of tropical woods, especially those used in plywood and furniture. Mr. Barefoot.

FOR 521, FOR 522. Chemistry of Wood and Wood Products **3-3**
Prerequisites: FOR 202, CH 215, CH 426, PY 212
Fundamental chemistry and physics of wood and wood components; pulping principles; electrical and thermal properties. Mr. Stamm.

FOR 531, FOR 532. Forest Management **3-3**
Prerequisite: FOR 372
Corequisite: FOR 511
Management of timber lands for economic returns; the normal forest taken as the ideal; the application of regulation methods to the forest.
Mr. Bryant.

FOR 533. Advanced Wood Structure and Identification **2-0**
Prerequisite: FOR 202
Advanced microscopic identification of the commercial woods of the United States and some tropical woods; microscopic anatomical features and laboratory techniques. Mr. Barefoot.

FOR 553. Forest Photogrammetry **0-2**
Prerequisites: FOR 372; FOR 531
Interpretation of aerial photographs, determination of density of timber stands and area mapping. Mr. Lammi.

FOR 571. Advanced Forest Mensuration **3-0**
Prerequisites: ST 311, FOR 372
Study of cyclical variation in growth of individual trees and stands; analysis of stand structures in even-aged versus all-age stands; general concepts of growing stock levels on yields; evaluation of growth prediction methods.
Mr. Maki.

FOR 572. Forest Policy **3-0**
Prerequisites: EC 201, FOR 219
Corequisite: FOR 531
Analysis of the forest policies of the United States and selected foreign countries; criteria for their evaluation; appraisal of current policies and alternatives. Mr. Lammi.

FOR 591. Forestry Problems **Credits by Arrangement**
Prerequisite: Senior or Graduate Standing
Assigned or selected problems in the field of silviculture, logging, lumber manufacturing, pulp technology, or forest management.
Graduate Staff.

FOR 599. Methods of Research in Forestry **Credits by Arrangement**
Prerequisite: Senior or Graduate Standing
Research procedures, problem outlines, presentation of results; consideration of selected studies by forest research organizations; sample plot technique.
Messrs. Ellwood, Maki, Zobel.

Courses for Graduates Only

FOR 601. Advanced Forest Management Problems **Credits by Arrangement**
Prerequisite: Graduate Standing
Directed studies in forest management.

FOR 603. Technology of Wood Adhesives **3 or 3**
Prerequisites: CH 425, CH 426, FOR 433
The fundamentals of adhesives as applied to wood-to-wood and wood-to-metal bonding. Technology of adhesives. Preparation and use of organic adhesives. Testing of adhesives and evaluation of quality of adhesives and bonded joints. Mr. Hart.

FOR 604. Timber Physics **3 or 3**
Prerequisite: FOR 441
Density, specific gravity and moisture content variation affecting physical properties; physics of drying at high and low temperatures; thermal, sound, light and electrical properties of wood. Messrs. Ellwood, Hart.

FOR 605. Design and Control of Wood Processes **3 or 3**
Prerequisite: FOR 604
Design and operational control of equipment for processing wood.
Mr. Ellwood.

FOR 606. Wood Process Analysis **3-0**
Prerequisites: FOR 512, FOR 604
Analysis of wood process through the solution of comprehensive problems involving the physics of temperature and moisture relations.
Mr. Ellwood.

FOR 607. Advanced Quality Control **0-3**
Prerequisites: FOR 606; ST 515
Advanced statistical quality control as applied to wood processing.
Mr. Hart.

FOR 611. Forest Genetics **3 or 3**
Prerequisites: GN 411 and Permission of Instructor
Application of genetic principles to silviculture, management and pulp utilization. Emphasis is on variations in wild populations, on the bases for selection and desirable qualities and on fundamentals of controlled breeding.
Mr. Zobel.

FOR 621. Advanced Wood Technology Problems **Credits by Arrangement**
Prerequisite: Graduate Standing
Selected problems in the field of wood technology. Graduate Staff.

FOR 691. Graduate Seminar **1-1**
Prerequisite: Graduate Standing in Forestry or Closely Allied Fields
Presentation and discussion of progress reports on research, special problems and outstanding publications in forestry and related fields.
Graduate Staff.

FOR 699. Problems in Research **Credits by Arrangement**
Prerequisite: Graduate Standing
Specific forestry problems that will furnish material for a thesis.
Graduate Staff.

DEPARTMENT OF GENETICS

Graduate Faculty

Professors: Thurston Jefferson Mann, *Head,* Carey Hoyt Bostian, Daniel Swartwood Grosch, Warren Durward Hanson, Harold Frank Robinson, Benjamin Warfield Smith, Stanley George Stephens
Associate Professors: Ken-Ichi Kojima, Dale Frederick Matzinger, Lawrence Eugene Mettler, Robert Harry Moll
Assistant Professors: Frank Bradley Armstrong, Gene Namkoong, Leroy Charles Saylor, Anastasios Christos Triantaphyllou

Associate Members of the Genetics Faculty

Professors: Jay Lawrence Apple, Fred Derward Cochran, Columbus Clark Cockerham, Dan Ulrich Gerstel, Edward Walker Glazener, Walton Carlyle Gregory, Paul Henry Harvey, Frank Lloyd Haynes, Jr., Teddy Theodore Hebert, Guy Langston Jones, Kenneth Raymond Keller, James Edward Legates, Thurston Jefferson Mann, Philip Arthur Miller, Daniel Townsend Pope, Hamilton Arlo Stewart, Donald Loraine Thompson, Nash Nicks Winstead, Bruce John Zobel
Associate Professors: Ernest Oscar Beal, William Lowery Blow, Charles Aloysius Brim, Will Allen Cope, Emmett Urcey Dillard, John Wesley Dudley, Donald Allen Emery, James Walker Hardin, Richard Robert Nelson, Thomas O. Perry, Lyle Llewellyn Phillips, John O. Rawlings, David H. Timothy
Assistant Professors: Gene John Galletta, W. R. Henderson, Joshua A. Lee, Odis Wayne Robison

Graduate study under direction of the genetics faculty may enable the student to qualify for the Master of Science or the Doctor of Philosophy degree. A candidate for the master's degree must acquire a thorough understanding of genetics and its relation to other biological disciplines and must present a thesis based upon his own research. In addition to a comprehensive knowledge of his field, a candidate for the doctorate must demonstrate his capacity for independent investigation and scholarship in genetics.

At North Carolina State there are no sharp divisions along departmental lines between theoretical and applied aspects of genetics research. The members and associate members of the genetics faculty are located in nine different departments of the School of Agriculture, the School of Forestry, and the School of Physical Sciences and Applied Mathematics. They are studying an extremely wide range of genetic problems and are utilizing not only the "classic" laboratory material (*Drosophila, Habrobracon,* maize, mice) but also farm animals and agricultural and horticultural plants of the region. A student has, therefore, a wide choice of research problems in any of the following fields: cytology and cytogenetics, physiological and irradiation genetics, forest genetics, population genetics, and the application

of quantitative genetics to breeding methodology. Arrangements with the School of Medicine at the University of North Carolina at Chapel Hill enable specialized study in human and medical genetics.

The offices and laboratories of the department are located in Gardner Hall with greenhouse facilities adjacent to the building. A genetics garden for use in the intensive research with plants and teaching functions is located three miles from the departmental offices. The departmental staff and the associate faculty members in Animal Science, Botany, Crop Science, Horticultural Science, Poultry Science, Plant Pathology, Experimental Statistics, and Forest Management are most fortunate in being able to draw upon the extensive facilities of the North Carolina Agricultural Experiment Station.

Courses for Advanced Undergraduates

GN 411. The Principles of Genetics **3 or 3**
Prerequisite: BO 103 or ZO 103
An introductory course. The physical and chemical basis of inheritance; genes as functional and structural units of heredity and development; qualitative and quantitative aspects of genetic variation.

Courses for Graduates and Advanced Undergraduates

GN 503. (See ANS 503. Genetic Improvement of Livestock.)

GN 512. Genetics **4-0**
Prerequisite: GN 411
Intended for students desiring more thorough and detailed training in fundamental genetics with some attention to physiological aspects. (Students conduct individual laboratory problems.) Mr. Grosch.

GN 513. Cytogenetics I **4-0**
Prerequisite: GN 512 or With Consent of Instructor
The chromosomes as vehicles of heredity. Mitosis and meiosis as bases of genetic stability and recombination. Structural and numerical aberrations and their effect upon the breeding systems of plants and animals. Interspecific hybrids and polyploids. Lectures and laboratory. Mr. Gerstel.

GN 520. (See PO 520. Poultry Breeding.)

GN 532. (ZO 532) Biological Effects of Radiations **0-3**
Prerequisite: ZO 103 or With Consent of Instructor
Qualitative and Quantitative effects of radiations (other than the visible spectrum) on biological systems, to include both morphological and physiological aspects in a consideration of genetics, cytology, histology, and morphogenesis. Mr. Grosch.

GN 540. (ZO 540) Evolution **3-0**
Prerequisite: GN 411
The facts and theories of evolution in plants and animals. The causes and consequences of organic diversity. (Offered in 1964-65 and alternate years.) Mr. Smith.

GN 541. (CS 541 and HS 541) Plant Breeding Methods **3-0**
Prerequisites: GN 512, ST 511 or Consent of Instructor
Principles and methods of plant breeding. Graduate Staff.

GN 542. (See CS 542 or HS 542. Plant Breeding Field Procedures.)

GN 550. Experimental Evolution **0-3**
Prerequisites: GN 512, GN 513 or Consent of Instructor
Experimental evolution deals primarily with micro-evolutionary processes examined at the inter- and intra-specific population level. A review of the results from experimental population studies and analyses of natural populations concerning variation patterns and adaptation, natural selection, polymorphism, introgression, population breeding structure, isolating mechanism, etc., is made and interpreted in relation to Neo-Darwinian concepts of the origin of species. Mr. Mettler.

GN 561. Biochemical and Microbial Genetics **3-0**
The course will include the development of the fields of biochemical and microbial genetics and will emphasize both the techniques and concepts utilized in current research. Mr. Armstrong.

Courses for Graduates Only

GN 602. (See ANS 602. Population Genetics in Animal Improvement.)

GN 607. (PP 607) Genetics of Fungi **3-0**
Prerequisite: GN 512 or Equivalent, Consent of Instructor
Review of major contributions in fungus genetics with emphasis on principles and theories that have evolved in recent developments. Mr. Nelson.

GN 611. (See FOR 611. Forest Genetics.)

GN 613. (See CS 613. Plant Breeding Theory.)

GN 626. (See ST 626. Statistical Concepts in Genetics.)

GN 631. Mathematical Genetics **3-0**
Prerequisites: GN 512, ST 511 or Consent of Instructor
History of mathematical biology, role of mathematical concepts in the development of genetic science, theory of genetic recombination, dynamics of genetic population. (Offered in 1963-64 and alternate years.)
Mr. Kojima.

GN 633. Physiological Genetics **0-3**
Prerequisite: GN 512
Recent advances in physiological genetics. Attention will be directed to literature on the nature and action of genes, and to the interaction of heredity and environment in the expression of the characteristics of higher organisms.

GN 641. Colloquium in Genetics **2-2**
Prerequisites: Graduate Standing; Consent of Instructor
Informal group discussion of prepared topics assigned by instructor.
Graduate Staff.

GN 691. Seminar **1-1**
Prerequisite: Graduate Standing

GN 695. Special Problems in Genetics **1 to 3 - 1 to 3**
Prerequisites: Advanced Graduate Standing, Consent of Instructor
Special topics designed for additional experience and research training.
Graduate Staff.

GN 699. Research **Credits by Arrangement**
Original research related to the student's thesis problem. A maximum of six credits for the Master's degree; by arrangement for the Doctorate.
Graduate Staff.

GEOLOGICAL ENGINEERING
(See Department of Mineral Industries)

DEPARTMENT OF HISTORY AND POLITICAL SCIENCE

Graduate Faculty

Professors: Preston William Edsall, *Head,* William Joseph Block, Marvin L. Brown, Jr., Fred Virgil Cahill, Jr., John Tyler Caldwell, Abraham Holtzman, Stuart Noblin
Associate Professors: Burton Floyd Beers, Ralph Weller Greenlaw

No graduate degrees are offered in history or political science at North Carolina State. Graduate programs leading to advanced degrees in this field are offered at the University of North Carolina at Chapel Hill. The courses listed below are eligible for graduate credit when they form a part of an approved graduate program in other departments, and work in history and political science may serve as a minor field.

Courses for Advanced Undergraduates

HI 401. Russian History **3-0**
This course presents the major trends in Russian social, political, economic, and cultural history, with emphasis on the nineteenth and twentieth centuries. USSR policy is studied in relation to the full sweep of Russian history.

HI 402. Asia and the West **0-3**
A history of Asia from the mid-nineteenth century to the present with emphasis on Asian nationalism and conflict with the imperial powers.

HI 409. Colonial America **2-0**
A study of the development of the American colonies in the seventeenth and eighteenth centuries, with special emphasis on European backgrounds.

HI 411. The American Revolution and the Confederation **3-0**
The historical steps in the establishment of the United States as an independent nation. The conflict with Great Britain after 1763 leading to the declaring of independence; the military and diplomatic aspects of the war for American independence; the peace negotiations and the peace settlement of 1783; the domestic problems and foreign relations in the immediate postwar years; the establishment of government in the new nation terminating with the adoption of the Constitution of 1787.

HI 412. Recent United States History **3 or 3**
A study of the main current in American political, economic, social, and diplomatic history of the twentieth century.

HI 422. History of Science **3-0**
A study of the evolution of science from antiquity to the present with particular attention given to the impact of scientific thought upon selected aspects of western civilization. The course provides a broad perspective of scientific progress and shows the interrelationship of science and major historical developments.

HI 491, HI 492. Seminar in History **3-3**
Prerequisite: Senior Standing in History; Open to Other Seniors and Graduate Students With Departmental Approval
A study of the works of significant historians and a survey of historical philosophies, theories, and techniques. Intensive reading on selected topics and exercises in research, criticism, and exposition.

PS 401. American Parties and Pressure Groups **3 or 3**
After a brief survey of those features of American government essential to an understanding of the political process, the course proceeds to examine the American electorate and public opinion and devotes its major attention to the nature, organization, and programs of pressure groups and political parties and to their efforts to direct opinion, gain control of government, and shape public policy. Special attention is given to party organization and pressure group activity at the governmental level and to recent proposals to improve the political party as an instrument of responsible government.

PS 406. Problems in State Government **0-2**
Prerequisite: PS 201 or An Acceptable Substitute
Selected problems arising from the operation of the legislative, administrative, and judicial machinery. In addition to acquiring a comprehensive view of these problems each student will make an intensive study of a special phase of one of them. Special attention will be given to North Carolina.

PS 431. International Organization **3-0**
Prerequisite: PS 201 or HI 205 or An Acceptable Substitute
A study of the evolving machinery and techniques of international organization in the present century with particular emphasis on recent developments. The actual operation of international organization will be illustrated by the study of selected current international problems.

PS 452. The Legislative Process **0-3**
A study of the formulation of public policy from the institutional and behavioral viewpoints. Important current legislative problems at the congressional and state legislative levels will be selected and will serve as a basis for analyzing the legislative process.

HI, PS 461. The Soviet Union **0-3**
An analysis of the structure and function of the major Soviet economic, political, and social institutions with special stress on the historical roots and continuity of Russian civilization. The course is presented in three equal phases of approximately five weeks each, covering Russian history, Soviet government, and Soviet economy.

PS 491, PS 492. Seminar in Political Science **3-3**
Prerequisite: Senior Standing in Political Science; Open to Other Seniors and Graduate Students With Departmental Approval
Emphasizing intensive independent work on selected topics, this seminar stresses familiarity with the literature and other resources of political science and further develops the student's skills in the methodology of the discipline.

Courses for Graduates and Advanced Undergraduates

PS 501. Modern Political Theory **3-0**
Prerequisite: PS 201 or HI 205 or An Acceptable Substitute
A study of the state and its relationship to individuals and groups, approached through the reading of selected passages from the works of outstanding political philosophers from the sixteenth century to the present.
Mr. Holtzman.

PS 502. Public Administration **0-3**
Prerequisite: PS 201 or PS 202 or An Acceptable Substitute
A study of the principles and problems of administration in public agencies, including such matters as organization, personnel, fiscal management, relationship to the legislative and judicial functions, control of administrative agencies and policies, and public relations.
Mr. Block.

PS 510. (EC 510) Public Finance **0-3**
Prerequisite: The Basic Course in Economics Required by the Degree Granting School
A survey of the theories and practices of government taxing, spending, and borrowing, including inter-governmental relationships and administrative practices and problems.
Mr. Block.

PS 512. American Constitutional Theory **0-3**
Prerequisite: PS 201 or An Acceptable Substitute
Basic constitutional doctrines, including fundamental law, judicial review, individual rights and political privileges, and national and state power. Specal attention is given to the application of these doctrines to the regulation of business, agriculture, and labor and the rights safeguarded by the First, Fifth, and Fourteenth Amendments to the Constitution.
Messrs. Cahill, Edsall.

HI 534. (RS 534) Farmers' Movements **0-3**
Prerequisite: Three Credits in American History, American Government, Sociology or A Related Social Science
A history of agricultural organizations and movements in the United States and Canada principally since 1865, emphasizing the Grange, the Farmers' Alliance, the Populist revolt, the Farmers' Union, the Farm Bureau, the Equity societies, the Nonpartisan League, cooperative marketing, government programs, and present problems.
Mr. Noblin.

Courses for Graduates Only

PS 691. Applied Principles of Public Administration **2-4 By Arrangement**
Prerequisite: PS 502 or An Acceptable Substitute
An advanced course in administrative principles and methods. Students will perform individual or group research, under supervision, in specific administrative topics within the context of those public agencies which function in their respective fields of technology.
Mr. Block.

PS 696. Problems in Political Science **2-4 By Arrangement**
Prerequisite: Advanced Graduate Standing
An independent advanced research course in selected problems of government and politics. The problems will be chosen in accordance with the needs and desires of the students registered for the course.

Graduate Staff.

DEPARTMENT OF HORTICULTURAL SCIENCE

Graduate Faculty

Professors: Fred Derward Cochran, *Head,* Monroe Evans Gardner, Frank Lloyd Haynes, Jr., John Mitchell Jenkins, Jr., Clarence Leslie McCombs, Daniel Townsend Pope
Associate Professors: Walter Elmer Ballinger, Thomas Franklin Cannon, Leaton John Kushman, Conrad Henry Miller
Assistant Professors: Gene John Galletta, Roy Axel Larson

The Department of Horticultural Science offers the Master of Science degree and the professional degree, Master of Horticulture. Evidence of high scholastic achievement in the basic biological sciences is particularly desirable for students who expect to study for the Master of Science degree in horticulture.

The department has excellent greenhouses, laboratories, cold storages, and access to adequate field plots, for graduate training in crop production, plant propagation, nutrition and physiology, biochemistry, morphology, plant breeding, cytology, and post-harvest physiology. The greenhouse range covers over 30,000 square feet of space and has twenty-one sections, each containing individual temperature and light control equipment. Laboratory facilities include four analytical laboratories, two cytological and anatomical laboratories, one soil testing laboratory for greenhouse control, one radioisotope laboratory, and one landscape and floral design laboratory. Post-harvest facilities include, additionally, fourteen controlled temperature storage rooms, and grading, washing and packaging equipment. These combined facilities provide a wide variety of opportunities in basic and technical research in the horticultural field. An extensive and varied assortment of plant materials is available for use in graduate programs.

The wide variations in climate and soils in North Carolina, from the coast to the mountains, make possible the study of plant responses under these varied conditions. Land and facilities for horticultural research are available on ten of the outlying stations located throughout the State.

The opportunities for employment after advanced training include teaching and research in state and privately endowed educational institutions; research and regulatory positions with the United States Department of Agriculture, both foreign and domestic; extension specialists and county agents; research, production and promotional work with food, chemical, and seed concerns; orchard, nursery and greenhouse supervisors; and inspectors and quality control technologists.

Courses for Advanced Undergraduates

HS 411. Nursery Management **3-0**
Prerequisites: BO 103, SSC 200
The principles and practices involved in the production, management, and marketing of field-grown and container-grown nursery plants. Field trips will be taken.

HS 421. Fruit Production **3-0**
Prerequisites: BO 103, SSC 200
A study of identification, adaptation, and methods of production and marketing of the principal tree and small fruits. Modern practices as related to selection of sites, nutritional requirements, management practices, and marketing procedures will be discussed.

HS 432. Vegetable Production **0-3**
Prerequisites: BO 103, SSC 200
A study of the origin, importance, distribution, botanical relationships, and principles of production and marketing of the major vegetable crops.

HS 441. Floriculture I **3-0**
Prerequisites: BO 103, SSC 200
The scope and importance of the commercial flower industry; the basic principles and practices involved in the production and marketing of flowers grown in the greenhouse and in the field.

HS 442. Floriculture II **0-3**
Prerequisites: BO 103, SSC 200
Principles and methods of production of commercial flower crops in the greenhouse and in the field, including fertilization, moisture, temperature, and light relationships, insect and disease control, and marketing of cut flowers and pot plants.

HS 471. Aboriculture **0-3**
Prerequisites: BO 103, SSC 200
A study of the principles and practices in the care and maintenance of ornamental trees and shrubs, such as pruning, fertilization, control of insects and diseases, and tree surgery. Field trips will be taken.

HS 481. Breeding of Horticultural Plants **3-0**
Prerequisite: GN 411
The application of genetic and other biological sciences to the improvement of horticultural crops.

Courses for Graduates and Advanced Undergraduates

HS 541. (GN 541 or CS 541) Plant Breeding Methods **3-0**
Prerequisites: GN 512; ST 511 Recommended
An advanced study of methods of plant breeding as related to principles and concepts of inheritance.

Messrs. Haynes, Timothy.

HS 542. (GN 542 or FC 542) Plant Breeding Field Procedures **2 in Summer Sessions**
Prerequisites: HS 541 or CS 541 or GN 541
Laboratory and field study of the application of various plant breeding techniques and methods used in the improvement of economic plants.
Graduate Staff.

HS 552. Growth of Horticultural Plants **0-3**
Prerequisite: BO 421
A study of the effect of nutrient-elements, water, light temperature, and growth substances on horticultural plants.
Messrs. Fish, Miller.

HS 562. Post-Harvest Physiology **0-3**
Prerequisite: BO 421
A study of chemical and physiological changes that occur during handling, transportation, and storage which affect the quality of horticultural crops. Consideration will be given to pre- and post-harvest conditions which influence these changes.
Messrs. Ballinger, McCombs.

HS 591. Senior Seminar **1-1**
Prerequisite: Senior in Horticulture
Presentation of scientific articles, progress reports in research, and special problems in horticulture and related fields.
Graduate Staff.

HS 599. Research Principles **Credits by Arrangement**
Prerequisite: Permission of Instructor
Investigation of a problem in horticulture under the direction of the instructor. The students obtain practice in experimental techniques and procedures, critical review of literature and scientific writing. The problem may last one or two semesters. Credits will be determined by the nature of the problem, not to exceed a total of 4 hours.
Graduate Staff.

Courses for Graduates Only

HS 613. (See CS 613. Plant Breeding Theory.)

HS 621. Methods and Evaluation of Horticultural Research **3-0**
Prerequisite: Graduate Standing
Principles and methods of research in the field of horticulture and their application to the solution of current problems. Critical study and evaluation of scientific publications. Compilation, organization, and presentation of data.
Mr. Cochran.

HS 691. Seminar **1-1**
Prerequisite: Graduate Standing
Presentation of scientific articles and special lectures. Students will be required to present one or more papers. Attendance of all graduate students is required.
Graduate Staff.

HS 699. Research **Credits by Arrangement**
Prerequisites: Graduate Standing in Horticulture; Consent of Chairman of Advisory Committee
Original research on specific problems in fruit, vegetable, and ornamental crops. Thesis prepared should be worthy of publication. A maximum of six credits is allowed toward the Master of Science degree; no limitation on credits in Doctorate program.

Graduate Staff.

DEPARTMENT OF INDUSTRIAL ARTS
(See School of Education)

DEPARTMENT OF INDUSTRIAL EDUCATION
(See School of Education)

DEPARTMENT OF INDUSTRIAL ENGINEERING

Graduate Faculty

Professors: Clifton A. Anderson, *Head,* Robert Gordon Carson, Jr., Robert W. Llewellyn
Visiting Professor: Rudolph Willard

The Department of Industrial Engineering offers graduate study leading to the Master of Science degree. The courses in this department reflect the new emphasis in the so-called operations research approach to the field.

Industrial engineering is concerned with the technical details of organizing men, materials, machines, capital and other resources to improve the efficiency of manufacturing, processing, and distribution activities. The basic education in industrial engineering emphasizes the utilization of the engineering sciences and mathematical and statistical analyses in the solution of planning, operating and control problems.

Courses for Advanced Undergraduates

IE 401. Industrial Engineering Analysis **3-0**
Prerequisites: IE 304; MA 405; ST 362
An introductory course in some of the more recently developed operations research techniques; applications of dynamic programming, replacement theory, Markov processes, queueing theory, linear programming; graphical methods of solutions; information theory and servomechanisms in Industrial Engineering. A balance will be sought between theory and practical applications.

IE 402. Industrial Engineering Analysis **0-3**
Prerequisite: IE 401
Continuation of IE 401.

IE 443. Quality Control **0-3**
Prerequisite: ST 361
Economic balance between cost of quality and value of quality, and techniques for accomplishing this balance. Organization for, specification and utilization of quality controls. Statistical theory and analyses as applied to sampling, control charts, tolerance determination, acceptance procedures and control of production.

Courses for Graduates and Advanced Undergraduates

IE 515. Process Engineering **3-0**
Prerequisites: IE 401; IE 443
The technical process of translating product design into a manufacturing program. The application of industrial engineering in the layout, tooling, methods, standards, costs and control functions of manufacturing. Laboratory problems covering producer and consumer products.
Graduate Staff.

IE 517. Automatic Processes **3-0**
Prerequisites: IE 401; IE 443
Principles and methods for automatic processing. The design of product, process, and controls. Economic, physical, and sociological effects of automation. Gradute Staff.

IE 521. Control Systems and Data Processing **3-0**
Prerequisite: IE 401
This course is designed to train the student in the problem and techniques required for systematic control of the production process and the business enterprise. This includes training in the determination of control factors, the collection and recording of data, and the processing, evaluation and use of data. The course will illustrate the applications and use of data processing equipment and information machines in industrial processes. Case problems will be used extensively.
Mr. Llewellyn.

IE 522. Dynomics of Industrial Systems **0-3**
Prerequisite: IE 401
A study of the dynamic properties of industrial systems; introduction to servomechanism theory as applied to company operations. Simulation of large nonlinear, multi-loop, stochastic systems on a digital computer; methods of determining modifications in system design and/or operating parameters for improved system behavior. Mr. Llewellyn.

IE 543. Standard Data **3-0**
Prerequisites: ST 361 or ST 515, One Course in Motion and Time Study
Theory and practice in developing standard data from stopwatch observations and predetermined time data; methods of calculating standards from data; applications of standard data in cost control, production planning and scheduling, and wage incentives. Mr. Anderson.

IE 546. Advanced Quality Control **0-3**
Prerequisite: IE 304 or ST 362
The statistical foundation of Quality Control is emphasized in this course

as well as its economic implications. Mathematical derivation of most of the formulas used is given. Sampling techniques are treated extensively and many applications of this powerful technique are explained.

Graduate Staff.

IE 547. Engineering Reliability **3-0**
Prerequisites: IE 353 or IE 304; ST 421
The methodology of reliability including application of discrete and continuous distribution models and statistical designs; reliability estimation, relability structure models, reliability demonstration and decisions, and reliability growth models. Examples of reliability evaluation and demonstration programs. Graduate Staff.

IE 551. Standard Costs for Manufacturing **0-3**
Prerequisites: One Course in Accounting; One Course in Motion and Time Study
The development, application and use of standard costs as a management tool; use of industrial engineering techniques in establishing standard costs for labor, material and overhead. Analysis of variances and setting of budgets. Measures of management performance. Mr. Willard.

IE 591. Project Work **2 to 6 - 2 to 6**
Prerequisite: Graduate or Senior Standing
Investigation and report on an assigned problem for students enrolled in the fifth-year curriculum in Industrial Engineering.

Graduate Staff.

Courses for Graduates Only

IE 621. Inventory Control Methods **0-3**
Prerequisite: Graduate Standing
A study of inventory policy with respect to recorder sizes, minimum points and production schedules. Simple inventory models, models with restrictions, price breaks, price changes, analysis of slow-moving inventories. Introduction to the smoothing problem in continuous manufacturing. Applications of linear and dynamic programming and zero-sum game theory.

Mr. Llewellyn.

IE 651. Special Studies in Industrial Engineering **Credits by Arrangement**
Prerequisite: Graduate Standing
The purpose of this course is to allow individual students or small groups of students to take on studies of special areas in Industrial Engineering which fit into their particular program and which may not be covered by existing industrial engineering graduate level courses. The work would be directed by a qualified staff member who had particular interest in the area covered by the problem. Such problems may require individual research and initiative in the application of industrial engineering training to new areas or fields. Graduate Staff.

IE 695. Seminar **1-1**
Seminar discussion of industrial engineering problems for graduate students. Case analyses and reports. Mr. Anderson.

IE 699. Industrial Engineering Research **Credits by Arrangement**
Graduate research in Industrial Engineering for thesis credit.

Graduate Staff.

DEPARTMENT OF MATHEMATICS

Graduate Faculty

Professors: John Wesley Cell, *Head,* Roberts Cozart Bullock, John Montgomery Clarkson, Walter Joel Harrington, Jack Levine, Carey Gardner Mumford, Howard Moyess Nahikian, *Graduate Administrator,* Hubert Vern Park, Hans Sagan, Darrell Rhea Shreve, Herbert Elvin Speece, Raimond Aldrich Struble, Hubertus Robert Van Der Vaart, Oscar Wesler, Lowell Sheridan Winton
Adjunct Professors: Alan Stuart Galbraith, Horace Maynard Trent
Associate Professors: John William Querry, Tsuan Wu Ting
Adjunct Associate Professor: Robert Taylor Herbst
Assistant Professors: John William Bishir, Bruce Edward Goodwin
Visiting Professor: Makoto Itoh

The Department of Mathematics offers graduate studies in applied mathematics leading to the Master of Applied Mathematics, the Master of Science, and the Doctor of Philosophy degrees. The Master of Applied Mathematics degree does not require a thesis nor a foreign language, but in all other respects it is the same as the Master of Science degree. Students who are admitted to the Graduate School to pursue studies in applied mathematics are expected to have had a strong undergraduate major in mathematics, including a year of advanced calculus and a year of modern algebra including abstract algebra and matrices. Those students who do not have these courses will be required to take them in addition to the minimum number required for the Master's degree. The areas of application require that the students offer a minor in some mathematically oriented area such as physics, the engineering sciences, or genetics.

Individuals with graduate training in applied mathematics are in great demand in industry, in governmental laboratories, and in college teaching positions. Opportunities are many and varied in this field and include work as a member of a research team in such areas as satelite orbit theory, viscoelasticity, biomathematics, thermodynamics, aerodynamics, acoustics, solid state physics, nuclear reactor theory, geophysics, and in applications of computers in business.

The department has available a number of teaching and research assistantships (a student holding a half-time assistantship is allowed to carry a study load of nine semester hours). Also available for those graduate students studying toward the Ph.D. degree are a limited number of NDEA and Ford Foundation fellowships.

Courses for Advanced Undergraduates

MA 401. Intermediate Differential Equations **3-3-3**
Prerequisite: MA 301
Theory of linear independence of solutions of linear differential equations, variation of parameters, superposition integral, simultaneous linear differential equations by transform methods, series solutions, special functions (Bessel, Legendre, etc.), orthogonal functions, and partial differential equations by separation of variables.

MA 403. Fundamental Concepts of Algebra **3-3-3**
Prerequisite: MA 202 or MA 212
Integers; integral domains; rational numbers; fields, rings, groups. Boolean algebra.

MA 404. Fundamental Concepts of Geometry **0-3**
Prerequisite: MA 202 or MA 212
Foundations of geometry; laws of logic; affine geometry; geometric transformations; homogeneous coordinates; comparison of Euclidean and non-Euclidean geometries.

MA 405. Introduction to Determinants and Matrices **3-3-3**
Prerequisite: MA 202 or MA 212
Properties of determinants; theorems of Laplace and Jacobi; systems of linear equations. Elementary operations with matrices; inverse, rank, characteristic roots and eigenvectors. Introduction to algebraic forms.

MA 421. Introduction to Probability **3-3**
Prerequisite: MA 202
Elementary probability theory primarily for students not intending to take further work in probability or theoretical statistics. Includes theory of sets, finite probability, conditional probability, compound experiments, Bayes' theorem, counting techniques, random variables, binominal and other distributions, generating functions, joint probability, continuous distributions.

MA 441. Advanced Calculus I **3-3-3**
Prerequisite: MA 301 and preferably a B-Average in Mathematics Courses Through MA 301 or MA 401
Partial differentiation and applications, vectors, Stieltjes integrals, multiple integrals.

MA 481. Special Topics in Mathematics **3-3**

MA 491. Reading for Honors in Mathematics **3-3**

Courses for Graduates and Advanced Undergraduates

MA 512. Advanced Calculus II **3-3-3**
Prerequisite: MA 441
Line and surface integrals, limits and indeterminate forms, infinite series, improper integrals. Graduate Staff.

MA 513. Introduction to Complex Variables **3-3-3**
Prerequisite: MA 512 or Consent of Department
Fundamentals of differentiation and integration; mapping by elementary functions; power series; residues and poles. Graduate Staff.

MA 514. Methods of Applied Mathematics **0-3-3**
Prerequisite: MA 512 or Consent of Department
Introduction to difference equations, integral equations, and calculus of variations. Graduate Staff.

MA 516. Principles of Mathematical Analysis **3-0**
Prerequisite: MA 512
The real number system, elements of set theory, limits, continuity, differen-

tiation, Riemann-Stieltjes integration, sequences of functions, fundamentals of Lebesgue theory, axiomatic development of set theory, topological and metric spaces. Graduate Staff.

MA 517. Introduction to Point-Set Topology **0-3**
Prerequisite: MA 516
A study of basic set-theoretic and general topological notions of modern mathematics. Topics include set theory and cardinal numbers, topological spaces, metric spaces, and elementary discussion of function spaces.
Graduate Staff.

MA 524. Boundary Value Problems **3-0**
Prerequisite: MA 441, MA 401 or MA 512
Theory of first variation with applications to various physical phenomena (vibrating string, vibrating membrane, heat conduction, and wave propagation); Bernoulli's separation theorem with application to vibration and heat conduction problems; Fourier series, Fourier-Bessel series, and Fourier-Legendre series and a full discussion of the Sturm-Liouville problem; and numerical approximation of eigenvalues by Rayleigh-Ritz method.
Graduate Staff.

MA 527. Numerical Analysis I **3-3-3**
Prerequisite: MA 441
Numerical solution of equations, introduction to the theory of errors, finite-difference tables and the theory of interpolation, numerical integration, numerical differentiation, and elements of difference calculus.
Graduate Staff.

MA 528. Numerical Analysis II **0-3**
Prerequisite: MA 527
Difference operators, summation procedures, numerical solution of ordinary differential equations, least-squares polynominal approximation, and Gaussian quadrature. Graduate Staff.

MA 532. Differential Equations **0-3**
Prerequisite: MA 441
Phase-plane concepts; elementary critical points and stability theory; second order linear equations with variable coefficents; general linear autonomous systems; forced oscillations of linear systems; Sturm-Liouville systems; eigenvalue problems and generalized Fourier expansions; existence and uniqueness theorems. Graduate Staff.

MA 536. Logic for Digital Computers **3-0**
Prerequisite: MA 441
Introduction to logic and formal languages of digital computers, algorithms, compilers, and heuristic programming. Graduate Staff.

MA 537. Non-numeric Uses of Computers **0-3**
Prerequisite: MA 536
The use of computers in problems not involving numerical analysis. Formal differentiation and integration, algebraic models, combinatorics, theorem proving and decision making. Problems of mechanical translation. Special computers. Graduate Staff.

MA 541. (ST 541) Theory of Probability I **3-0**
Prerequisite: MA 441
Axioms, discrete and continuous sample spaces, events, combinatorial analysis, conditional probability, repeated trials, independence, random variables, expectation, special discrete and continuous distributions, probability and moment generating functions, central limit theorem, laws of large numbers, branching processes, recurrent events, random walk. [Offered also in special summer sessions at Virginia Polytechnic Institute (1964) and University of Florida (1965).] Graduate Staff.

MA 542. (ST 542) Theory of Probability II **0-3**
Prerequisites: MA 405, MA 541
Markov chains and Markov processes, Poisson process, birth and death processes, queueing theory, renewal theory, stationary processes, Brownian motion, information theory. Graduate Staff.

MA 555. (PY 555) Principles of Astrodynamics **0-3**
Prerequisites: MA 441; PY 411 or EM 312
The differential equations of motion in two-body problems and their integrals; orbit theory; integrals of the n-body problem; differential equations of motion of natural and artificial satellites and their approximate solutions. Graduate Staff.

MA 581. Special Topics **3-3**
Prerequisite: Consent of Department Graduate Staff.

Courses for Graduates Only

MA 602. Partial Differential Equations **0-3**
Prerequisite: MA 512
Ordinary differential equations in more than two variables, partial differential equations of the first order, partial differential equations of the second order, Laplace's equation, the wave equation, the diffusion equation. Mr. Struble.

MA 605. Non-Linear Differential Equations **3-0**
Prerequisites: MA 512, MA 532
Phase-plane and phase-space concepts; existence and uniqueness theorems; continuity, analytic and differentiability properties of solution; properties of linear systems; stability in non-linear systems; topological methods; perturbations of periodic solutions; asymptotic methods and resonance problems. Mr. Struble.

MA 608. Integral Equations **0-0-3**
Prerequisites: MA 512, MA 532
Linear Volterra integral equations of the first and second kinds. Relationship to linear differential initial value problems. Special Volterra equations of the convolution type. Singular Volterra equations. Linear Fredholm integral equations of the first and second kind. Basic theory. Symmetric kernels. Hilbert-Schmidt theory (generalizations). Mr. Winton.

MA 611. Complex Variable Theory and Applications I **3-0**
Prerequisite: MA 512
Elementary functions; analytic functions and Cauchy-Riemann equations;

conformal mapping and applications; Taylor and Laurent series; contour integration and residue theory; the Schwarz-Christoffel transformation.

Mr. Bullock.

MA 612. Complex Variable Theory and Applications II **0-3**
Prerequisite: MA 611
Conformal mapping and applications to flow phenomea; multiple-valued functions and Riemann surfaces; further applications of residue theory; analytic continuation; infinite series and asymptotic expansions; elliptic functions and other special functions in the complex domain; representation theorems. Mr. Bullock.

MA 615. Theory of Functions of a Real Variable I **3-0**
Prerequisites: MA 516, MA 517 or Consent of Department
Sets and spaces; continuity of functions; measure, measurable sets and functions. Mr. Harrington.

MA 616. Theory of Functions of a Real Variable II **0-3**
Prerequisite: MA 615
The Lebesgue integral; summable functions; absolute continuity; the space L_2. Mr. Harrington.

MA 621. Introduction to Modern Abstract Algebra **3-0**
Prerequisite: MA 512
A study of the abstract structure and properties of groups, rings and ideals, and fields. Messrs. Nahikian, Park.

MA 622. Vector Spaces and Matrices **0-3-3**
Prerequisite: MA 405 or Consent of Department
A study of vector spaces and their relation to the theory of matrices. Matrix inversion, linear transformations, including similarity and orthogonal transformations, canonical forms. Properties of the characteristic and reduced characteristic function. Elementary divisors and functions of matrices. Applications to systems of differential equations.

Messrs. Nahikian, Park.

MA 625. Introduction to Differential Geometry **0-0-3**
Prerequisite: MA 512
Theory of curves and surfaces in 3-dimensional euclidean space with special reference to those properties invariant under the rigid body motions.

Mr. Levine.

MA 632. Operational Mathematics I **3-0**
Corequisite: MA 513 or MA 611
Laplace transform with theory and application to problems in ordinary and partial differential equations arising from engineering and physics problems; Fourier integral and Fourier transforms and applications.

Mr. Cell.

MA 633. Operational Mathematics II **0-3**
Prerequisite: MA 632
Extended development of the Laplace and Fourier transforms and their uses in the solution of problems in ordinary and partial differential equations and in difference equations; Sturm-Liouville systems; advanced theory in ordinary and partial differential equations; Z-transforms, other infinite and finite transforms and their applications. Mr. Cell.

MA 635. Mathematics of Computers **0-3**
Prerequisites: MA 335, MA 512, MA 528
Corequisite: MA 405 or MA 622
The development of methods for the solution of selected problems involving matrices; integral rational equations; ordinary and partial differential equations. Particular attention is paid to the question of convergence and stability; examples solved on the IBM 650. Graduate Staff.

MA 641. Calculus of Variations **0-0-3**
Prerequisite: MA 512
The simplest problem of the calculus of variations in detail; variable endpoints; iso-perimetric problems; Hamilton's principle; least action principle; introduction to the theory of linear integral equations of the Volterra and Fredholm types. Mr. Winton.

MA 651. Expansion of Functions **0-0-3**
Prerequisites: MA 611, MA 633 or Equivalent
Expansion of functions of one or more variables in Taylor series; asymptotic series; infinite products, partial fractions, continued fractions, series of orthogonal functions; applications in ordinary partial differential equations, difference equations and integral equations.
Messrs. Cell, Harrington.

MA 661. Tensor Analysis I **3-0**
Prerequisite: MA 512
The basic theory, tensor algebra, tensor calculus, invariants of quadratic differential forms; covariant differentiation; geometric applications, Riemannian spaces; generalized vector analysis. Mr. Levine.

MA 662. Tensor Analysis II **0-3**
Prerequisite: MA 661
Continuation of MA 661, physical applications; dynamics, Legrange's equations, the geometry of dynamics, cofiguration spaces. Further applications to electromagnetic theory and elasticity. Mr. Levine.

MA 681. Special Topics in Analysis **Up to 6 Hours Credit**

MA 683. Special Topics in Algebra **Up to 6 Hours Credit**

MA 685. Special Topics in Numericol Analysis **Up to 6 Hours Credit**

MA 687. Special Topics in Geometry **Up to 6 Hours Credit**

MA 689. Special Topics in Applied Mathematics **Up to 6 Hours Credit**
The above courses, MA 681-MA 689, afford opportunities for graduate students to study advanced topics in mathematics under the direction of members of the graduate staff. These will on occasion consist of one of several areas such as, for example, advanced theory of partial differential equations, topology, mathematics of elasticity or of viscoelasticity, orbital mechanics, functional analysis, combinatorial analysis. Graduate Staff.

MA 699. Research in Mathematics **Credits by Arrangement**
Prerequisites: Graduate Standing, Approval of Adviser
Individual research in the field of mathematics. Graduate Staff.

DEPARTMENT OF MECHANICAL ENGINEERING

Graduate Faculty

Professors: Robert Wesley Truitt, *Head,* Norval White Conner, Jesse Seymour Doolittle, *Graduate Administrator,* Karl P. Hanson, Hassan Ahmad Hassan, Richard Bennett Knight, Toyoki Kogi, Robert McLean Pinkerton, James Woodburn

Associate Professors: Munir R. El-Saden, Bertram Howard Garcia, Richard Shao-Lin Lee, Mehmet Necati Ozisik, Frederick Otto Smetana, John Kerr Whitfield, James Clifford Williams, III., James T. Yen, Carl Frank Zorowski

Assistant Professors: Thomas Benson Ledbetter, Huseyin Cavit Topakoglu, Sridhar M. Ramachandra

The Department of Mechanical Engineering offers graduate study leading to the Master of Science and Doctor of Philosophy degrees. Entrance to the various programs in the department is normally based upon an accredited baccalaureate degree in engineering.

At present, the major emphases in graduate study are the thermal sciences, including classical thermodynamics, heat transfer and transport phenomena, statistical thermodynamics and direct energy conversion; gas dynamics (aerothermochemistry, aerothermodynamics, plasmagasdynamics, magnetogasdynamics and rarefied gasdynamics) and the mechanical sciences, such as principles of fluid motion, dynamics of compressible flow and viscous fluids, vibrations, mechanical transients and stress analysis; the aerospace science of aerodynamics, propulsion, boundary layer theory and heat transfer, and spacecraft design.

The professional technological interests of the department are represented by graduate courses in nuclear power plants, steam and gas turbines, refrigeration, internal combustion engines, lubrication, mechanics of machinery, and machine design analysis and synthesis.

Graduate programs in mechanical engineering normally include substantial work in the basic sciences of mathematics and physics, and study in related engineering departments is encouraged.

The fundamental objective of graduate study in this field is to prepare the student for leadership in the various categories of research, teaching, and design. The graduate student is placed in close association with the graduate faculty who conduct individual research. Participation in a research project as a research assistant or employment as a teaching assistant is regarded as significant experience during residence.

Courses for Advanced Undergraduates

ME 401. Energy Conversion **3 or 3**
Prerequisite: ME 302

A course on the conversion of energy for engineering purposes based upon the fundamentals leading to engineering decisions in the arrangement and selection of energy conversion equipment. The conventional type of plant for energy conversion and the unconventional types, in particular, direct energy conversion and the feasibility of such plants. Factors which effect the cost of power and elements entering into the problem of monetary rates.

ME 402. Heat and Mass Transfer **3 or 3**
Prerequisites: ME 302, MA 301
A study of the fundamental relationships of steady and transient heat transfer by conduction, convection, radiation and during changes of phase; mass transfer by diffusion and convection; simultaneous mass and heat transfer.

ME 405. Mechanical Engineering Laboratory III **1-0**
Prerequisite: ME 306
Required of Seniors in Mechanical Engineering
The selection of appropriate instrumentation and the experimental analysis of small, predetermined engineering systems designed for flexibility and wide variation of parameters. Systems cover the gamut of Mechanical Engineering activity with emphasis on analysis of system rather than characteristics of particular systems.

ME 406. Mechanical Engineering Laboratory IV **0-1**
Prerequisite: ME 405
Individual or small group investigation of an original problem under the supervision of a faculty member with an interest in the problem area. The investigation may be experimental, analytical, or both. Emphasis is placed on the philosophy and methodology of engineering research, and on individual thinking and effort.

ME 410. Jet Propulsion **0-3**
Prerequisites: ME 302 and ME 352 or EM 303
Application of fundamental principles of thermodynamics and the mechanics of a compressible fluid to the processes of jet-propulsion and turbo-propeller aircraft; the effect of performance of components on performance of engine; analysis of engine performance parameters.

ME 411, ME 412. Mechanical Design I, II **3-3**
Prerequisites: EM 301, MIM 201, ME 315
Required of Seniors in Mechanical Engineering
Application of the basic principles of the mechanical sciences to the analysis and design of machines, devices and mechanical systems. Consideration of the complete design process including formulation of design concepts, synthesis of components, analysis of the assembly, and evaluation of the finalized design. Project activity with design orientation.

ME 421. Aerospace Propulsion Systems **0-3**
Prerequisite: ME 353
Corequisite: ME 461
A study of propulsion systems and their relation to the various flight regimes and space missions. The principles of thrust generation, the control, and the performance of various propulsion systems will be considered.

ME 431. Thermodynamics of Fluid Flow **3 or 3**
Prerequisites: MA 301, EM 303 or ME 352, ME 302
The fundamental dynamics and thermodynamic principles governing the flow of gases are presented from both theoretical and experimental viewpoints. Mathematical relations are closely correlated with physical phenomena to emphasize the complimentary nature of theory and experiment.

ME 432. Boundary Layer Theory and Heat Transfer **0-3**
Prerequisites: C or Better in ME 352; MA 401 or MA 441
The course is intended to give the student both a physical and mathematical understanding of the problems of skin friction and heat transfer in present-day aerospace engineering.

ME 435. Industrial Automatic Controls **3 or 3**
Prerequisites: ME 301, MA 301
Introduction to concept of automatic controls; fundamentals of two-position, proportional, floating and rate modes of control with a graphical and analytical presentation of each. Theoretical considerations of the process and an introduction to system analysis.

ME 441. Technical Seminar **1 or 1**
Prerequisite: Graduating Senior Standing.
Meetings once a week for the delivery and discussion of student papers on topics of current interest in Mechanical Engineering.

ME 447. Performance, Stability and Control of Flight Vehicles **3-0**
Prerequisites: C or Better in ME 352; MA 401 or MA 441
A study of aerodynamic and inertial factors and how they influence the motion of flight vehicles and their performance. The transfer function approach is emphasized in the analysis of flight vehicle motion.

ME 461. Aerospace Technology **3-0**
Prerequisites: PY 208, EM 200, MA 301, ME 353
An introduction to the principles of flight in and beyond the atmosphere. Includes the elements of aerodynamics of flight, the reentry problem, flight dynamics, guidance and control, power generation in space, manned and unmanned space flight and life support systems.

ME 465, ME 466. Aerospace Engineering Laboratory **1-1**
Prerequisites: ME 306, ME 352
Laboratory experience in wind tunnel experimentation, structural testing, environmental testing, and instrumentation for flight in and beyond the atmosphere.

ME 468. Spacecraft Structures **3-0**
Prerequisite: ME 369
Corequisite: ME 461
Basic techniques and procedures in the analysis of stresses and strains caused by the extreme heating of reentry space vehicles as well as the dynamic and impulsive loads occurring during the launching and loading period of flight will be considered and the resulting effects on the vehicle structure will be studied.

ME 481. Flight Vehicle Design **0-5**
Prerequisites: ME 352, ME 461, ME 468, ME 447, ME 421, EE 202
Integration of previous aerodynamic, heat transfer, materials, structures, and dynamical theory in the design of typical air-supported and space vehicles and their sub-systems.

Courses for Graduates and Advanced Undergraduates

ME 501. Steam and Gas Turbines **3-3**
Prerequisites: ME 302 and EM 303 or ME 352
Fundamental analysis of the theory and design of turbomachinery flow passages; control and performance of turbomachinery; gas-turbine engine processes. Mr. Doolittle.

ME 507, ME 508. Internal Combustion Engine Fundamentals **3-3**
Prerequisite: ME 302
The fundamentals common to internal combustion engine cycles of operation. The Otto engine: carburetion, fuel distribution, flame propagation, normal and knocking combustion, throttling, pumping, valve and spark timing, and altitude effects; the Diesel engine: injection and spray formation fuel rating, atomization, penetration, diesel knock, combustion, precombustion, and scavenging as applied to reciprocating and rotary engines. Mr. Ledbetter.

ME 515. Experimental Stress Analysis **3-0**
Prerequisite: ME 315
Theoretical and experimental techniques of strain and stress analysis, with experimental emphasis on electrical strain gages and instrumentation, brittle coatings, grid methods, and photoelasticity. Laboratory includes a full experimental investigation and report of a problem chosen by the student under the guidance of the instructor. Mr. Whitfield.

ME 516. Photoelasticity **0-3**
Prerequisite: ME 411
Two and three-dimensional photoelasticity; the stress-optic law, isochromatics, isoclinics, stress trajectories, fractional orders of interference; three-dimensional techniques, oblique incidence, rotational and thickness effects; determination of principal stresses at interior points; laboratory investigations. Mr. Whitfield.

ME 517. Lubrication **0-3**
Prerequisite: EM 303
The theory of hydrodynamic lubrication; Reynold's equation, the Sommerfield integration, effect of variable lubricant properties and energy equation for temperature rise. Properties of lubricants. Application to design of bearings. Boundary lubrication. Mr. Woodburn.

ME 521. Aerothermodynamics **3-3**
Prerequisites: ME 301, MA 301 and EM 303 or ME 352
An examination of the basic concepts of gas dynamics such as the continuum, domain of applicability of continuum, acoustic velocity, compressibility effects, and the conservation laws. Analysis of one dimensional flows such as isentropic flow, adiabatic flow, flow with friction, the normal shock. An introduction to the vector formulation of multi-dimensional problems. Mr. Lee.

ME 541, ME 542. Aerodynamics Heating **3-3**
Prerequisites: MA 441 and ME 521 or Equivalent
A detailed study of the latest theoretical and experimental findings of the compressible laminar and turbulent boundary layers with special attention to the aerodynamic heating problem; application of theory in the analysis and design of aerospace hardware. Mr. Williams.

ME 545, ME 546. Project Work in Mechanical Engineering I, II **2 or 2**
Individual or small group investigation of a problem stemming from a mutual student-faculty interest. Emphasis is placed on providing a situation for exploiting student curiosity. Graduate Staff.

ME 554. Advanced Aerodynamic Theory **0-3**
Prerequisite: ME 352
Development of fundamental aerodynamic theory. Emphasis upon mathematical analysis and derivation of equations of motion, airfoil theory and comparison with experimental results. Introduction to supersonic flow theory. Mr. Pinkerton.

ME 562. Advanced Aircraft Structures **0-3**
Prerequisite: ME 468
Development of methods of stress analysis for aircraft structures, special problems in structural design, stiffened panels, rigid frames, indeterminate structures, general relaxation theory. Mr. Topakoglu.

ME 571. Air Conditioning **3-0**
Prerequisite: ME 302
A fundamental study of summer and winter air conditioning including temperature, humidity, air velocity and distribution. Mr. Knight.

ME 572. Refrigeration **0-3**
Prerequisite: ME 302
A thermodynamic analysis of the simple, compound, centrifugal and multiple effect compression systems, the steam jet system and the absorption system of refrigeration. Mr. Knight.

ME 581, ME 582. Hypersonic Aerodynamics **3-3**
Prerequisites: MA 512 and ME 521 or Equivalent
A detailed study of the latest theoretical and experimental findings in hypersonic aerodynamics. Mr. Truitt.

Courses for Graduates Only

ME 601. Advanced Engineering Thermodynamics **3-0**
Prerequisite: ME 302
First and Second Laws; theory of variable specific heats; general equations of thermodynamics; characteristic equations of state; reduced coordinates; prediction of properties of gases and vapors; chemical equilibrium; metastables; thermodynamics of fluid flow. Mr. El-Saden.

ME 602. Statistical Thermodynamics **0-3**
Prerequisites: ME 601, MA 441
Fundamental principles of kinetic theory, quantum mechanics, statistical mechanics and irreversible phenomena with particular reference to thermodynamics systems and processes. The conclusions of the classical thermodynamics are analyzed and established from the microscopic viewpoint.
Mr. El-Saden.

ME 603. Advanced Power Plants **3-0**
Prerequisite: ME 401
A critical analysis of the energy balance of thermal power plants, thermo-

dynamics and economic evaluation of alternate schemes of development; study of recent developments in the production of power.

Mr. Doolittle.

ME 605. Aerothermochemistry **0-3**

Prerequisites: ME 601 and MA 441 or Equivalent

A generalized treatment of combustion thermodynamics including derivation of thermodynamic quantities by the method of Jacobians, criteria for thermodynamic equilibrium, computation of equilibrium composition and adiabatic flame temperature. Introduction to classical chemical kinetics. Conservation equations for a reacting system, detonation and deflagration. Theories of flame propagation, flame stabilization, and turbulent combustion. Mr. Lee.

ME 606. Advanced Gas Dynamics **0-3**

Prerequisites: ME 521, ME 601, MA 441

The general conservation equations of gas dynamics from a differential and integral point of view. Hyperbolic compressible flow equations, unsteady one-dimensional flows, the non-linear problem of shock wave formation, isentropic plane flow, flow in nozzles and jets, turbulent flow.

Mr. Smetana.

ME 608. Advanced Heat Transfer I **0-3**

Prerequisite: ME 402 or Equivalent

Fundamental aspects, from an advanced viewpoint, will be considered in the conduction of heat through solids, convective phenomena, and the measurement and prediction of appropriate physical properties. Boundary value problems arising in heat conduction will be examined and both numerical and function solution techniques developed. Internal and external boundary layer analyses will be made on a variety of representative convection situations. Mr. Ozisik.

ME 609. Advanced Heat Transfer II **0-3**

Prerequisite: ME 608

Advanced topics in the non-isothermal flow of fluids through channels will be investigated for slug, laminar, transitional and turbulent conditions. The influence of mass transfer on flow and heat transfer processes will be considered. Radiation exchange processes between solid surfaces, and solid surfaces and gases both stationary and moving will be discussed.

Mr. Ozisik.

ME 610. Advanced Topics in Heat Transfer **3-0**

Prerequisite: ME 609

This course constitutes a study of recent developments in heat transfer and related areas. It is anticipated that the course content will change from semester to semester. Mr. Ozisik.

ME 611, ME 612. Advanced Machine Design I, II **3-3**

Prerequisite: ME 412

Kinematics of mechanical media, the stress tensor, the tensor of strains, elasticity, plasticity, time-dependent behavior; theories of failure, working stresses; shock and steady dynamic loading, creep, stress concentration, thermal stress, contact stresses; energy theories, finite difference and relaxation methods; hydrodynamic lubrication. Application to the design of machine frames, shafts, bearings, gears, springs, cams, etc.

Mr. Zorowski.

ME 613. Mechanics of Machinery **3-0**
Prerequisites: ME 315, MA 512
Vector dynamics, d'Alembert's principle, Lagrange's equations; rigid kinematics, Euler's angles, rigid rotation, Coriolis accelerations; the inertia tensor. Application to mechanisms, gyroscopes, guidance and control systems, rotating and reciprocating devices. Mr. Zorowski.

ME 614. Mechanical Transients and Machine Vibrations **0-3**
Prerequisites: ME 315; MA 401 or 441
Dynamic loads in mechanical media are considered in two categories—steady vibrations and transient shock and impact. The Lagrange equations and the wave equation are employed to study internal stresses and displacements in mechanical devices which result from such loading.
Mr. Zorowski.

ME 615. Aeroelasticity I **3-0**
Prerequisites: MA 441, ME 411 or ME 468, ME 521
Deformations of aero structures under static and dynamic loads, natural mode shapes and frequencies; two and three dimensional incompressible flow, wings, and bodies in unsteady flow; static aeroelastic phenomena.
Mr. Topakoglu.

ME 616. Aeroelasticity II **0-3**
Prerequisite: ME 615
Flutter, dynamic response phenomena such as transient landing stresses, gusts, continuous atmospheric turbulence; aeroelastic model theory, model design and construction. Mr. Topakoglu.

ME 617. Plates and Shells in Mechanical Design **0-3**
Prerequisites: MA 441, ME 611
The concept of members which are thin in one dimension, that is, plates and shells, is applied to mechanical design with particular emphasis on type of loading, conditions of service, and compliance of the member to its environment. Mr. Garcia.

ME 625, ME 626. Direct Energy Conversion **3-3**
Prerequisite: ME 601
An engineering study of the modern developments in the field of conversion of heat to power in order to meet new technology demands. Thermoelectric, thermomagnetic, thermionic, photovoltaic and magnetohydrodynamic effects and their utilization for energy conversion purposes, static and dynamic response, limitations imposed by the first and the second laws of thermodynamics. Energy and entropy balances, irreversible sources; inherent losses, cascading, design procedures, experimental studies to determine the response and efficiency of various systems. Mr. El-Saden.

ME 631. Applications of Ultrasonics to Engineering Research **3-0**
Prerequisites: MA 441, EE 332
The technique and theory of propagation of ultrasonics in liquids, gases and solids. Development of ultrasonic transducers, the elastic piezoelectric and dielectric relationships. Ultrasonic applications of asdic or sonar cavitation, emulsification, soldering, welding, and acoustic properties of gases, liquids and solids. Mr. Woodburn.

ME 651. Principles of Fluid Motion **3-0**
Prerequisite: ME 453
Corequisite: MA 511
Fundamental principles of fluid dynamics. Mathematical methods of analysis are emphasized. Potential flow theory development with introduction to the effects of viscosity and compressibility. Two dimensional and three dimensional phenomena are considered. Mr. Pinkerton.

ME 652. Dynamics of Compressible Flow **3-0**
Prerequisites: ME 521, MA 441
Properties of compressible fluids, equation of motion in one-dimensional motion, channel flows, shock wave theory, methods of observation, and flows at transonic speeds. Mr. Pinkerton.

ME 653. Supersonic Aerodynamics **0-3**
Prerequisite: ME 652
Equations of motion in supersonic flow, Prandtl-Meyer turns, method of characteristics, hodograph plane, supersonic wind tunnels, supersonic airfoil theory, and boundary layer shock interaction. Mr. Yen.

ME 654. Dynamics in Viscous Fluids **0-3**
Prerequisite: ME 651
Development of the Navier-Stokes equations and the boundary layer theory. Laminar and turbulent boundary layers in theory and experiment, flow separation, and transition. Mr. Williams.

ME 657. Measurement in Rarefied Gas Streams **3-0**
Prerequisite: ME 602
A study of the basis for measurement of flow properties in rarefied gas streams. Included will be ionization gauges, hot wire anemometers and temperature probes, pitot and static tubes, Langmuir probes, electron scattering and electron beam density gauges. Mr. Smetana.

ME 658, ME 659. Molecular Gasdynamics **3-3**
Prerequisites: ME 521, ME 602
Statistical mechanics as applied to the derivation of the equations of gasdynamics from the microscopic viewpoint. Energy levels of atoms and molecules and their relation to equilibrium thermodynamic concepts, in particular, specific heats. Approximate solutions of the Boltzmann Equation. Treatments of viscosity, heat conduction, and electrical conductivity. Collision processes. High temperature behavior of multispecies gas mixtures.
Mr. Smetana.

ME 660. Aero-Mechanical Engineering Problems **0-3**
Prerequisites: ME 402, MA 514
Derivation of governing equations and set up of representative problems in heat transfer, gas dynamics, and magneto-hydrodynamics; review of techniques for solving these problems. Introduction of other techniques such as method of steepest descent, method of Weiner-Hopt. variational methods and others. Phase-space and function space concepts will be introduced also. Purpose of the course in the graduate program is to strengthen the analytical techniques of the students in dealing with aero-mechanical engineering problems so that in their later studies more emphasis may be put on formulation of new problems and physical interpretation of new results.
Mr. Yen.

ME 661, ME 662. Aerospace Energy Systems **3-3**
Prerequisites: MA 512, ME 521, PY 407 or Equivalent
A study of energy systems appropriate to the varied requirements of space operations. Includes analysis of chemical, nuclear and solar energy sources and the theory of their adaptation to operational requirements for propulsion and auxiliary power, cooling requirements, coolants and materials.
Mr. Truitt.

ME 671, ME 672. Advanced Air Conditioning Design I, II **3-3**
Prerequisites: ME 571, ME 572
The design of heating and air conditioning systems; the preparation of specifications and performance tests on heating and air conditioning equipment. Mr. Knight.

ME 681. Introduction to Rocket Propulsion **3-0**
Prerequisite: ME 601
Review of the exterior ballistics and performance of rocket propelled vehicles. Thermodynamics of real gases at high temperatures. Non-equilibrium flow in rocket nozzles. Mr. Hassan.

ME 682. Solid Propellant Rockets **0-3**
Prerequisite: ME 681
A study of the design and performance of solid-propellant rockets; properties and burning characteristics of solid propellants. Internal ballistics of solid propellant rockets. Design and design optimization. Combustion instabilities. Mr. Hassan.

ME 683. Liquid Propellant Rockets **0-3**
Prerequisite: ME 681
The study and design of liquid propellant rockets. Combustion of liquid fuels. Thrust chamber, propellant supply and injection system. Cooling of rocket motors. Low and high frequency instability in liquid rocket motors. Scaling laws. Mr. Hassan.

ME 691, ME 692. Advanced Spacecraft Design **3-3**
Prerequisites: ME 542, ME 582
Analysis and design of spacecraft including system design criteria, acceleration tolerance, entry environment, thermal requirements, criteria for configuration design, aerodynamic design, heating rates, thermostructural design, boost phase, de-orbit, entry corridor, lift modulation, rolling entry, glide phase, maneuvering and landing, stability and control, thermal protection system, materials, instrumentation, and life support systems.
Mr.Truitt.

ME 693. Advanced Topics in Mechanical Engineering **1 to 6**
Prerequisite: Graduate Standing
Faculty and graduate student discussions of advanced topics in contemporary Mechanical Engineering. Graduate Staff.

ME 695. Mechanical Engineering Seminar **1 or 1**
Faculty and graduate student discussions centered around current research problems and advanced engineering theories. Graduate Staff.

ME 699. Mechanical Engineering Research **Credits by Arrangement**
Prerequisite: Graduate Standing in Mechanical Engineering and Approval of Adviser
Individual research in the field of Mechanical Engineering.
Graduate Staff.

METALLURGICAL ENGINEERING
(See Department of Mineral Industries)

DEPARTMENT OF MINERAL INDUSTRIES

Graduate Faculty

Professors: William Wyatt Austin, *Head,* William Callum Bell, William Wurth Kriegel, John Mason Parker, III, Hans Heinrich Stadelmaier, Robert Franklin Stoops
Adjunct Professor: Henry Mauzee Davis
Associate Professors: Henry Seawell Brown, William Cullen Hackler, John Valentine Hamme, Carlton James Leith, Hayne Palmour, III
Visiting Associate Professor: Joachim-Dietrich Schobel
Assistant Professor: William Calvin Hood

The Department of Mineral Industries offers graduate programs leading to the degrees of Master of Science in ceramic engineering, geological engineering, and metallurgical engineering, and to the Doctor of Philosophy degree in ceramic engineering. Certain graduate courses are also offered for the benefit of students majoring in other areas who may be interested in pursuing advanced work in the mineral industries fields.

Financial assistance is available to graduate students in the Department of Mineral Industries. Graduate assistantships permit half-time studies in either ceramic engineering, geological engineering, or metallurgical engineering, and half time to be devoted to teaching or other assigned duties. Also, certain sponsored fellowships that permit full time to be devoted to graduate studies, such as the Edward Orton, Jr. Ceramic Foundation Fellowship, the International Lead Zinc Research Organizations Fellowship in Ceramics, and the Ford Foundation Fellowships, are available. Applications should be made to the department.

Ceramic Engineering

The potentially superior characteristics of ceramics for many advanced engineering applications in space, nuclear, and industrial technologies presents many challenging opportunities for basic research in this rapidly expanding materials science. Present programs at N. C. State are characterized by intensive study and research in establishing intrinsic properties and elucidating governing mechanisms as functions of structure and environment. Crystalline ceramics are being investigated as single crystals (sapphire, ruby, and spinel grown in the Engineering Research Department's High Temperature Crystal Laboratory) and as polycrystalline compacts produced by sinter-

ing and hot pressing. Traditional glass bonded, polyphase ceramics in a variety of product areas are under investigation.

Statistically designed experimentation to study the properties of glasses have been initiated. Phase studies in the uranium-carbon-oxygen-nitrogen system are continuing.

The prerequisite for graduate work in ceramic engineering is a proficiency in the undergraduate courses required for the bachelor's degree in ceramic engineering, or substantial equivalent.

The department's ceramic laboratories are well equipped for research work. These facilities are augmented by those of the Ceramic Research Laboratories of the Department of Engineering Research. Also available are the Electron Microscope, X-Ray Diffraction, Crystal Growing, and Phase Equilibria Laboratories of that department, the Nuclear Reactors of the Physics and Nuclear Engineering Departments, and the computer facilities of the Experimental Statistics Department.

Geological Engineering

The graduate program in geological engineering is directed to the advanced training of qualified students interested in the professional economic applications of geological knowledge. The occupational fields include the locating of mineral resources, and the assessing of geological conditions at the sites of large civil engineering projects. Candidates for admission to this program should hold the Bachelor of Geological Engineering degree or a satisfactory equivalent, preferably including a strong background in physics, chemistry, and engineering sciences.

The solution of professional problems in geology is today requiring more specialized training and quantitative methods than can be included in an undergraduate curriculum. A person with such training in geology finds employment with petroleum, mining, and construction companies, governmental agencies, and educational research institutions.

A great variety of problems in igneous, sedimentary, and metamorphic geology are to be found within a radius of fifty miles of North Carolina State.

Facilities are available for research in mineralogy, petrography, economic geology, mineral dressing, and geologic problems relating to civil engineering. Excellent collections of geological literature are available at North Carolina State, at the University of North Carolina at Chapel Hill, and at Duke University in Durham. A well staffed unit of the Ground Water division of the U. S. Geological Survey is housed nearby on the campus and is available for consultation.

Metallurgical Engineering

The rapid development of space and nuclear technology and attendant materials problems has brought about a sharp increase in the demand for trained leaders in the materials fields. There is at present intense emphasis on advanced study and research on the fundamental behavior of metals and

alloys. From this work will come urgently-needed improvements in metallic materials of construction to withstand increasingly drastic service requirements—higher stresses, higher temperatures, corrosive and radioactive environments.

Opportunities for men with graduate training in metallurgy and metallurgical engineering are almost unlimited. Industry and universities today need approximately four times as many metallurgists with advanced degrees as are available. It has been estimated that by 1975 the electrical, chemical, aircraft, and nuclear industries will require 50,000 research metallurgists and metallurgical engineers. The number presently available is approximately 8,000. Present ratios indicate that one-third to one-half of the 50,000 graduates needed should have advanced training beyond the bachelor's degree. The shortage of graduates with advanced degrees is further accentuated by the need for qualified college faculty members to provide adequate instruction in metallurgical and related fields.

North Carolina State is one of the few institutions in the South, and the only institution in North Carolina, prepared to offer graduate instruction in metallurgical engineering. In addition to the advanced work in metallurgical engineering, the School of Engineering also offers an excellent program of supporting courses at the graduate level in the related fields of physics, chemistry, mathematics, engineering mechanics, and in mechanical, chemical, ceramic, and nuclear engineering.

Ceramic Engineering

Courses for Advanced Undergraduates

MIC 415, MIC 416. Ceramic Engineering Design **3-3**
Prerequisites: MIC 306, EM 301
A two-semester study to encourage creative solutions to problems of current interest and need in the ceramic profession. Discussion of sources of data, design principles, creativity, optimization, economic value analysis and decision making. Individual and team study involving interdependence of plant layout, processes, equipment and materials in the design of engineering systems or sub-systems. Study of factors in utilization of ceramics in materials systems.

MIC 425. Seminar **1-1**
One Semester Required of Seniors in Ceramic Engineering
A Second Semester May Be Elected
Literature survey of selected topics in ceramic engineering. Oral and written reports, discussions.

MIC 430. Research and Control Methods **3-0**
Prerequisite: MIC 306
Interpretation of results, instrumental methods applied to research and product development. Statistical quality control.

MIC 431. Reaction Kinetics in Ceramic Systems **0-4**
Prerequisites: MIM 201, CH 431
A study of reactions taking place during thermal treatment of ceramic

systems. Such topics as thermodynamics, heterogeneous phase equilibria, diffusion, solid state reactions, nucleation and grain growth are treated.

MIC 432. Glass Phase **4-0**
Prerequisite: MIC 431
A study of the glassy state to include the structure, properties, and types of glasses (including glazes and enamels). Opacity, color, and devitrification. Nature of the glassy phase in kiln fired ceramics.

MIC 433. Ceramic Microstructure and Properties **0-4**
Prerequisite: MIC 431
A study of the properties and behavior of processed ceramics from the standpoint of their phase characterization, atomic, micro-and macrostructure. Characteristics of ceramics are interpreted in terms of basic mechanisms affecting thermal, electronic, magnetic, mechanical, optical and nuclear properties. Emphasis is placed on process treatment and environmental effects.

Courses for Graduates and Advanced Undergraduates

MIC 501, MIC 502. Ceramic Structural Analysis **3-3**
Prerequisite: MIG 331
Basic laws of crystal structures. Arrangement of ions in crystals. Estimation of phases present in multi-coponent systems utilizing x-ray techniques. Analysis of glass structure. Correlation of structure with composition and properties. Mr. Hamme.

MIC 503. Ceramic Microscopy **3 or 3**
Prerequisite: MIG 331
Transmitted and reflected light techniques for the systematic study of ceramic materials and products. Interpretation and representation of results.
Mr. Hackler.

MIC 506. Electron Microscopy **3 or 3**
Prerequisite: MIC 503 or PY 404 or EE 507
The theory of the realization of electrostatic and magnetic lenses for electron microscopy. Major emphasis is placed on interpretation of electron diffraction and surface replications of ceramics and metals. Mr. Lucier.

MIC 509. High Vacuum Technology **3 or 3**
Prerequisite: CH 433 or ME 301
Properties of low pressure gases and vapors. Production, maintenance, and measurement of high vacuum; design, construction, and operation of high vacuum, high temperature facilities. Properties and reactions of materials which are processed, tested, and/or utilized in high vacuum environments.
Mr. Palmour.

MIC 527. Refractories in Service **3 or 3**
Prerequisite: CH 433
A study of the physical and chemical properties of the more important refractories in respect to their environment in industrial and laboratory furnaces. Mr. Kriegel.

MIC 529. Properties of High Temperature Materials **3 or 3**
Prerequisite: MIM 201
Effect of temperature on the physical, mechanical and chemical properties of inorganic materials; relationships between microstructure and high temperature properties; uses of ceramics, cermets, and metals at extremely high temperatures. Mr. Stoops.

MIC 533, MIC 534. Advanced Ceramic Engineering Design **3-3**
Prerequisites: MIC 416, MIC 433
Advanced studies in analysis and design of ceramic products, processes, and systems leading to original solutions of current industrial problems and the development of new concepts of manufacturing. Mr. Palmour.

MIC 540. Glass Technology **3 or 3**
Prerequisite: MIC 432
Fundamentals of glass manufacture including compositions, properties and application of the principle types of commercial glasses. Mr. Kriegel.

MIC 548. Technology of Cements **3 or 3**
Prerequisite: MIC 431
The technology of the Portland cement industry including manufacture, control and uses. Mr. Kriegel.

MIC 596, MIC 597. Advanced Ceramic Experiments **3-3**
Prerequisite: MIC 430 or Equivalent
Advanced studies in ceramic laboratory experimentation. Graduate Staff.

Courses for Graduates Only

MIC 601. Ceramic Phase Relationships **3 or 3**
Prerequisite: Consent of Instructor
Heterogeneous equilibrium, phase transformations, dissociation, fusion, lattice energy, defect structure, thermodynamic properties of ionic phases and silicate melts. Mr. Hackler.

MIC 603. Advanced Ceramic Reaction Kinetics **3 or 3**
Prerequisite: MIC 431, MIC 501
Fundamental study of the kinetics of high temperature ceramic reactions such as diffusion, nucleation, grain growth, recrystalization, phase transformation, vitrification and sintering. Mr. Stoops.

MIC 611. Ceramic Process Analysis **3 or 3**
Prerequisite: MIC 502
Corequisite: ST 516
Analysis of experimental and production data for ceramic processes. Quantitative evaluation of the effect of materials, materials preparation, heat distribution, composition, and other variables on properties. Sampling from production. Linear programing to compound glass and cement batches. Mr. Hackler.

MIC 621. The Vitreous State **3 or 3**
Prerequisite: MIC 540
An advanced study of the structure of binary and ternary silicate and borate glasses. Influence of structure on properties of vitreous systems.
Mr. Hackler.

MIC 631, MIC 632. Advanced Physical Ceramics I, II **3-3**
Corequisites: MIC 501, MIC 502 or MIM 521, MIM 522, EM 501, EM 502 or PY 503, PY 552
Lattice structures and lattice energies in crystalline ceramics; relationships with elastic, optical, and thermal properties. Effects of constitution and microstructure on lattice-sensitive properties. The defect crystalline state in ceramics: vacancies, color centers, dislocations, boundaries. Crystal growth. Plastic deformation processes, including creep and fatigue; the ductile-brittle transition. Structure-sensitive properties of cystalline, vitreous and composite ceramics; effects of constitution, microstructure, non-stoichiometry.
Mr. Palmour.

MIC 635, MIC 636. Electronic Ceramics **3-3**
Prerequisites: MA 441 and PY 407 or PY 414 or EE 531
Lattice energy, dielectric and optical properties of insulators, ferroelectrics, magnetic oxides, electron distribution in insulators and semiconductors; electronic properties of alkali halides. Mr. Stadelmaier.

MIC 695. Ceramic Engineering Seminar **1-1**
Reports and discussion of special topics in ceramic engineering and allied fields. Graduate Staff.

MIC 697. Special Studies in Ceramic Engineering **1 to 3 Credits Per Semester**
Special studies of advanced topics in ceramic engineering. Credit will vary with the topic. Graduate Staff.

MIC 699. Ceramic Research **Credits By Arrangement**
An original and independent investigation in ceramic engineering. A report of such an investigation is required as a graduate thesis. Graduate Staff.

Geological Engineering

Courses for Advanced Undergraduates

MIG 415. Mineral Exploration and Evaluation **0-3**
Prerequisites: MIG 440, MIG 452
Application of the principles of geology, geophysics, and geochemistry to the discovery and evaluation of mineral deposits. Design of mineral exploration and development programs based on knowledge of the unique thermodynamic, geochemical, and tectonic features that control mineral formation and concentrations in well known mining districts, especially those yielding ferrous, base, and precious metals. Review of economic and technological factors governing the value of mineral deposits.

MIG 440. Endogenic Materials and Processes **0-4**
Prerequisites: MIG 220, MIG 331
Minerals, rocks, and mineral deposits that are formed at high temperatures and pressures by crystallization or solidification of molten magma, or by

solid state recrystallization of older rocks. Application of principles of thermodynamics and of phase-rule chemistry, and the results of modern high pressure-temperature laboratory research on the stability fields of crystalline phases, to an understanding of igneous and metamorphic rocks. Identification, classification, occurrence, origin, and economic value of the principal igneous and metamorphic rocks.

MIG 452. Exogenic Materials and Processes **4-0**
Prerequisites: MIG 220, MIG 331
Identification, classification, geologic occurrence, origin, and economic value of minerals, rocks, and mineral deposits formed by physical, chemical, and biological processes at low temperatures and pressures at and near the earth's surface. Hydrodynamics of sediment transport and deposition, settling velocities and size sorting, chemical and biochemical precipitation from aqueous solutions, principles of division of stratified terranes into natural units, correlation of strata, identification of depositional environments, and facies analysis.

MIG 461. Engineering Geology **3 or 3**
Prerequisite: MIG 120 or MIG 220
The application of geologic principles to engineering practice; analysis of geological factors and processes affecting specific engineering projects.

MIG 462. Geological Surveying **0-3**
Prerequisites: MIG 351, MIG 440, MIG 452
Required of Seniors in Geological Engineering
Methods of field observation and use of geologic surveying instruments in surface and underground work; representation of geologic features by maps, sections and diagrams. Lectures, laboratories, and field work.

MIG 465. Geological Field Procedures **6 Summer**
Prerequisite: MIG 351 or Special Permission
A six week summer field course. Practical field procedures and instruments commonly used to procure geologic data for evaluating mineral deposits, solving engineering problems involving earth materials, and drawing scientific conclusions. Observation of geologic phenomena in their natural setting. Large and intermediate scale geologic mapping of surface features and large scale mapping underground in mine workings.

MIG 472. Elements of Mining Engineering **3-0**
Prerequisite: MIG 220 and at Least Junior Standing in Geological Engineering.
Introduction to mining; surface and underground methods of development and production; explosives, drilling and blasting; ore loading, transport, and hoisting; drainage and ventilation; mine surveying and sampling; fire assaying; mining law, organization, administration, and safety. Lectures, laboratory and field inspections.

Courses for Graduates and Advanced Undergraduates

MIG 522. Petroleum Geology **3 or 3**
Prerequisite: MIG 452
Properties, origin and modes of occurrence of petroleum and natural gas. Geologic and economic features of the principal oil and gas fields, mainly in the United States. Mr. Leith.

MIG 552. Exploratory Geophysics **0-3**
Prerequisites: MIG 351, PY 202
Fundamental principles underlying all geophysical methods; procedure and instruments involved in gravitational, magnetic, seismic, electrical, and other methods of studying geological structures and conditions. Spontaneous potential, resistivity, radioactivity, temperature, and other geophysical logging methods. Study of applications and interpretations of results.
Mr. Leith.

MIG 563. Applied Sedimentology **0-3**
Prerequisite: MIG 452
Advanced treatment of the geological aspects of erosion and sediment transport and deposition, especially as related to engineering works, and to land and water utilization. Analysis of physical, mineralogical, and some chemical properties of sediments and sedimentary rocks; interpretation of these properties in terms of depositional basins and environments. Mr. Leith.

MIG 565. Hydrogeology **3-0**
Prerequisite: MIG 452
Occurrence and sources of surface and subsurface water. Relationship of surface water to subsurface water. Rock properties affecting infiltration, movement, lateral and vertical distribution, and quality of ground water. Determination of permeability, capacity, specific yield, and other hydraulic characteristics of quifers. Principles of well field design. Legal aspects of water supplies. Mr. Hood.

MIG 567. Geochemistry **3-0**
Prerequisite: CH 231 or CH 433
The quantitative distribution of elements in the earth's crust, the hydrosphere, and the atmosphere. Application of the laws of chemical equilibruim and resultant chemical reactions to natural earth systems. Geochemical applications of Eh-pH diagrams. Geochemical cycles. Isotope geochemistry.
Mr. Hood.

MIG 571, MIG 572. Mining and Mineral Dressing **3-3**
Prerequisite: MIG 472
Principles of the mineral industry; mining laws, prospecting, sampling, development, drilling, blasting, handling, ventilation and safety; administration, surveying, assaying; preparation, benefication and marketing.
Graduate Staff.

MIG 581. Geomorphology **3-0**
Prerequisite: MIG 452
A systematic study of land forms and their relations to processes and stages of development and adjustment to underlying structure. Lectures, map interpretations, and field trips. Mr. Brown.

MIG 593. Advanced Topics in Geological Engineering **1 to 6-1 to 6**
Prerequisite: Permission of Staff
Special study of some advanced phases of geological engineering.
Graduate Staff.

Courses for Graduates Only

MIG 611, MIG 612. Advanced Economic Geology **3-3**
Prerequisites: MIG 440, MIG 452
Detailed study of the origin and occurrence of specific mineral deposits.
Mr. Brown.

MIG 632. Microscopic Determination of Opaque Minerals **3 or 3**
Prerequisite: MIG 331
Identification of metallic, opaque minerals in polished sections by physical properties, etch reactions and microchemical tests. Laboratories.
Mr. Brown.

MIG 642. Advanced Petrography **3 or 3**
Prerequisites: MIG 331, MIG 440
Application of the petrographic microscope to the systematic study of the composition and origin of rocks; emphasis on igneous and metamorphic rocks. Graduate Staff.

MIG 695. Seminar **1-1**
Prerequisite: Graduate Standing
Scientific articles, progress reports and special problems of interest to geologists and geological and mining engineers discussed.
Graduate Staff.

MIG 699. Geological Research **Credits by Arrangement**
Prerequisite: Permission of the Instructor
Lectures, reading assignments, and reports; special work in Geology to meet the needs and interests of the students. Graduate Staff.

Metallurgical Engineering

Courses for Advanced Undergraduates

MIM 401, MIM 402. Metallurgical Operations I, II **4-4**
Prerequisite: MIM 332
A systematized treatment of the fundamental operations involved in the production and fabrication of metals and alloys. Part I deals primarily with procedures and operations employed in chemical or extractive metallurgy. Part II covers the operations of physical and mechanical metallurgy.

MIM 421, MIM 422. Metallurgy I, II **2-2**
Prerequisite: CH 102
Required of Seniors in M.E. and M.E.A.
The constitution, structure and properties of engineering ferrous and nonferrous metals and alloys; influences of mechanical working and heat treatment; physical testing, corrosion and its prevention.

MIM 423. Metallurgical Laboratory **1 or 1**
Corequisite: MIM 421 or MIM 422
Laboratory work to accompany Metallurgy I, II.

MIM 431, MIM 432. Metallography I, II **3-3**
Prerequisite: MIM 332
An intensive study of the principles and techniques for examination and correlation of the structure, constitution, and properties of metals and alloys.

MIM 451, MIM 452. Metallurgical Engineering Seminar **1-1**
Prerequisite: Senior Standing in Metallurgical Engineering
Reports and discussion of special topics in metallurgical engineering and related subjects.

Courses for Graduates and Advanced Undergraduates

MIM 521, MIM 522. Advanced Physical Metallurgy I, II **3-3**
Prerequisite: MIM 422
Theories concerning behavior and control of engineering alloys, reaction rates in the solid state, and alloy influences; current heat treating practices; surface treatments; behavior of metals at high and low temperatures; special purpose alloys; powder metallurgy; review of modern equipment and methods for the study of metals. Mr. Stadelmaier.

MIM 523, MIM 524. Metallurgical Factors in Design **3-3**
Prerequisite: MIM 422
A study of the metallurgical factors that must be considered in using metals in design. Mr. Austin.

MIM 541, MIM 542. Principles of Corrosion I, II **3-3**
Prerequisite: MIM 422
The fundamentals of metallic corrosion and passivity. The electro-chemical nature of corrosive attack, basic forms of corrosion, corrosion rate factors, methods of corrosion protection. Laboratory work included.
Mr. Austin.

MIM 561. Advanced Structure and Properties of Materials **3-0**
Prerequisite: MIM 422
A systematic treatment of the fundamental physico-chemical principles governing the constitution of both metallic and ceramic materials. Correlation of these principles with physical, mechanical and chemical properties of materials. Particular emphasis is placed upon materials of construction for nuclear reactors. Lecture and Laboratory. Mr. Austin.

MIM 562. Materials Problems in Nuclear Engineering **0-3**
Prerequisite: MIM 561
Engineering aspects of problems involved in the selection and application of reactor materials. Specific attention is given to elevated temperature behavior, fatigue, corrosion, irradiation damage, and the fabrication and processing of these materials. Lecture and Laboratory. Graduate Staff.

MIM 595, MIM 596. Advanced Metallurgical Experiments I, II **3-3**
Prerequisite: MIM 422 or Approval of Instructor
Advanced engineering principles applied to a specific experimental project dealing with metallurgy or metallography. A seminar period is provided, and a written report is required. Graduate Staff.

Courses for Graduates Only

MIM 651, MIM 652. Theory and Structure of Metals **3-3**
Prerequisite: MIM 522
An advanced interpretation of the development of theories of the metallic state with emphasis on modern physical concepts. Topics include theory of crystallinity, bonding forces, stability of metallic structures, diffusion, and dislocation theory. Mr. Stadelmaier.

MIM 699. Metallurgical Engineering Research **Credits by Arrangement**
Independent investigation of an appropriate problem in Metallurgical Engineering. A report on this investigation is required as a graduate thesis.
Graduate Staff.

DEPARTMENT OF MODERN LANGUAGES

Graduate Faculty

Professors: George W. Poland, *Head,* Edward M. Stack

The Department of Modern Languages courses listed below are recommended to assist graduate students in preparing themselves for the use of modern foreign languages in research and advanced study. Students are given the opportunity of working a translation project in connection with their subject of major interest. They are encouraged particularly to seek in this instance useful foreign research related to thesis or other research in progress. Although these courses do not carry graduate language credit, they may be taken as a means of attaining a reading knowledge.

Certification may be obtained in languages not normally taught by the department with special permission of the Graduate School.

MLR 101, MLR 102. Russian **3-3**
These two courses are given for graduate students only, the first dealing with grammar and structure and the second with reading of Russian scientific material.

MLF 401. French Grammar for Graduate Students **3-3**
This course is designed to present the grammar of scientific French as rapidly as possible in preparation for the reading course which follows.

MLF 402. Scientific French **3-3**
Prerequisite: MLF 401 or Equivalent
Reading and translation of technical French, supplemented by discussions on terminology, word order, vocabulary analysis and other linguistic techniques. Subject material adjusted to individual needs; conferences.

MLS 401. Spanish Grammar for Graduate Students **3-3**
This course is designed to present the grammar of scientific Spanish as rapidly as possible in preparation for the reading course which follows.

MLS 402. Scientific Spanish **3-3**
Prerequisite: MLS 401 or Equivalent
Reading and translation of technical Spanish, supplemented by discussions on terminology, word order, vocabulary analysis and other linguistic techniques. Subject material adjusted to individual needs; conferences.

MLG 401. German Grammar for Graduate Students **3-3**
This course is designed to present the grammar of scientific German as rapidly as possible in preparation for the reading course which follows.

MLG 402. Scientific German **3-3**
Prerequisite: MLG 401
Reading and translation of technical German, supplemented by discussions on terminology, word order, vocabulary analysis and other linguistic techniques. Subject material adjusted to individual needs; conferences.

DEPARTMENT OF NUCLEAR ENGINEERING

Graduate Faculty

Professors: Raymond LeRoy Murray, *Head,* Harold Augustus Lamonds*

Affiliated Graduate Faculty

Professors: Wesley Osborne Doggett, *Physics,* James K. Ferrell, *Chemical Engineering,* Arthur W. Waltner, *Physics*
Associate Professors: Alonzo Freeman Coots, *Chemistry,* Munir R. El-Saden, Necati Ozisik, *Mechanical Engineering,* Edward George Manning, *Electrical Engineering*
Assistant Professors: Lawrence Hoffman Bowen, *Chemistry,* Robert Walter Lade, *Electrical Engineering*

The Department of Nuclear Engineering offers graduate study leading to the Master of Science and Doctor of Philosophy degrees.

Courses and research are available within the department and cooperating departments in several areas of nuclear engineering, including reactor theory and analysis, radiation attenuation and detection, energy transfer and conversion, nuclear materials, and instrumentation.

Among the available research facilities are a 100-kilowatt heterogeneous reactor, a pulsed positive ion Van de Graaff accelerator, digital and analog computers, a high pressure heat transfer loop, and plasma physics laboratories. Close associations are maintained with many departments in the School of Engineering and the School of Physical Sciences and Applied Mathematics.

Candidates for admission are expected to hold the bachelor's degree in one of the fields of engineering or the physical sciences. Experience in nuclear physics, advanced differential equations, and basic reactor theory will reduce the time required for completion of the degree. Courses in these areas can be included in the initial phases of the graduate program. Thirty credit hours (including four for research) and a thesis are required for the Master of Science degree. Especially well-qualified students may study directly toward the Doctor of Philosophy degree.

The Department of Nuclear Engineering participates in the Nuclear Science and Engineering Fellowship Program of the Atomic Energy Commission. Students are also eligible for fellowships from the Ford Foundation, the National Science Foundation, the National Aeronautics and Space Agency, and others. A few half-time graduate assistantships are available in which a nine credit-hour load per semester is permitted.

* On leave until July, 1964.

Graduates of the department find positions in industry, government, and academic institutions. Opportunities include analysis, design, utilization, and operation of nuclear facilities associated with the nuclear aerospace program, power reactors, research reactors, and radioisotopes.

Courses for Advanced Undergraduates

NE 404. Nuclear Energy Conversion I **0-3**
Prerequisite: ChE 421 or equivalent
Basic principles of the transformation of nuclear energy into useful forms. Considers the reactor as a heat source for a heat engine cycle. Description and analysis of various reactor concepts and associated power plants.

NE 405. Nuclear Energy Conversion II **3-0**
Prerequisite: ChE 422 or equivalent
Basic principles of the transformation of nuclear energy into useful forms. Considers isotope production and utilization, direct conversion techniques, nuclear propulsion concepts, research reactors, and breeder reactors.

Courses for Graduates and Advanced Undergraduates

NE 501. Nuclear Reactor Theory I **3-0**
Corequisite: PY 410
An introductory course in reactor theory including the fission process, neutron energy distribution, lethargy, neutron slowing and interactions, diffusion, Fermi age theory, the diffusion equation, criticality conditions, and reactor instrumentation. Mr. Verghese.

NE 502. Nuclear Reactor Theory II **0-3**
Prerequisite: NE 501
Continuation of reactor theory from NE 501. Topics include: treatment of reactor parameters for homogeneous and heterogeneous reactors, reflected reactors, multi-group theory, reactor kinetics, temperature effects, control rod theory, perturbation theory, and transport theory. Mr. Verghese.

NE 503. Nuclear Engineering Systems **0-3**
Prerequisite: NE 501
Considers reactor as a system including aspects of reactor control, radiation protection, shielding, and thermal design. Mr. Carnesale.

NE 511. Radiation Detection and Analysis **2-2**
Prerequisite: PY 410
Interaction of radiation with detectors. Characteristics of detectors and analysis equipment. Statistics of the counting process. Emphasis is on preparation for use of radiation counting equipment for research. Mr. Verghese.

NE 530. Introduction to Nuclear Reactor Theory **0-3**
Prerequisite: PY 410
The principles of neutron motion in matter, with emphasis on the analysis of the nuclear chain reactor. Slowing of neutrons, diffusion, space distributions of flux, conditions for criticality, group theories, and the time-dependent behavior of fissionable assemblies. Graduate Staff.

NE 531. Nuclear Reactor Laboratory **1-1**
Prerequisite: NE 530 or NE 501
Observation and measurements of static and dynamic nuclear reactor behavior, the effectiveness of control and temperature, and correlation with theory. Experiments on the motion and detection of neutrons and gamma rays, with emphasis on the research uses of nuclear reactor radiations.
Graduate Staff.

NE 540. Nuclear Reactor Control **0-3**
Prerequisite: NE 502 or NE 530
Considers non-steady-state reactor behavior including reactivity effects due to temperature, poisoning, and control rods. Uses elementary servomechanism theory in treating reactor as a control element. Treats automatic control including control mechanisms and dynamic effect of power plant characteristics. Mr. Leonard.

NE 545. Nuclear Reactor Kinetics **3-0**
Prerequisite: NE 502 or NE 530
The kinetic behavior of nuclear reactors is carefully analyzed from both theoretical and experimental viewpoints. Solutions of the basic kinetic equations are developed and applied to specific reactor behavior. Temperature, void, and xenon poisoning effects are considered. Digital and analog computer techniques are discussed and utilized. Correlation of theory with observed reactor behavior is made and safety considerations in reactor design are discussed. Mr. Leonard.

NE 591, NE 592. Special Topics in Nuclear Engineering I, II **3-3**
Prerequisite: Consent of the Instructor
These courses will be used to explore unusual and/or specialized areas of nuclear engineering. Graduate Staff.

Courses for Graduates Only

NE 619. Reactor Theory and Analysis I **3-0**
Prerequisite: NE 502 or NE 530
The theory of neutron slowing, resonance capture, Doppler effect, and thermal flux distributions in heterogeneous nuclear reactors. Analysis of reactor control by temperature, effects of localized and distributed absorbers, fission products, fuel consumption and production. One-velocity neutron transport theory. Mr. Murray.

NE 620. (PY 620) Nuclear Radiation Attenuation **3-0**
Prerequisites: NE 502 or NE 530 or PY 510, MA 512
The physical theory and mathematical treatment of the penetration of neutrons, gamma-rays, and charged particles in matter. Gamma-ray transport theory. Analysis of experimental methods for obtaining penetration data.
Mr. Doggett.

NE 630. Reactor Theory and Analysis II **0-3**
Prerequisite: NE 502 or NE 530
The theory of neutron multiplication in uniform media with several dimensions, regions, and neutron energy groups. Reactor control by absorbers,

time dependent reactor behavior, matrix treatment of perturbation theory, neutron thermalization, energy dependent neutron transport theory, and multigroup machine methods. Mr. Murray.

NE 691, NE 692. Advanced Topics in Nuclear Engineering I, II **3-3**
Prerequisite: Consent of the Instructor
A study of recent developments in nuclear engineering theory and practice. Graduate Staff.

NE 695. Seminar in Nuclear Engineering **1-1**
Discussion of selected topics in nuclear engineering. Graduate Staff.

NE 699. Research in Nuclear Engineering **Credits by Arrangement**
Individual research in the field of nuclear engineering. Graduate Staff.

DEPARTMENT OF OCCUPATIONAL INFORMATION AND GUIDANCE

(See School of Education)

DEPARTMENT OF PHILOSOPHY AND RELIGION

Courses for Advanced Undergraduates

PHI 401. Symbolic Logic **3 or 3**
Modern methods in logic involving formalized expression that avoids inherent difficulties and ambiguities of ordinary language and make possible greater effectiveness in handling complex material.

REL 403. Religions of the World **3 or 3**
Background, general characteristics, and basic teachings of the major living religions of the world; consideration of contemporary secular movements that are in a sense religions.

PHI 405. Foundations of Science **3 or 3**
Nature and validity of knowledge, basic concepts of modern science, scientific method, and the implications of the philosophy of modern science for ethics, social philosophy, and the nature of reality.

DEPARTMENT OF PHYSICS

Graduate Faculty

Professors: Dudley Williams, *Head,* Willard Harrison Bennett, Wesley Osborne Doggett, Harry Charles Kelly, Forrest Wesley Lancaster, Edward Manring, Jefferson Sullivan Meares, Arthur Clayton Menius, Jr., Raymond Leroy Murray, Arthur W. Waltner

Professor Emeritus: Rufus Hummer Snyder

Associate Professors: William Robert Davis, Joseph Thomas Lynn, *Graduate Administrator*

Assistant Professors: Grover Cleveland Cobb, Jr., Gerald Howard Katzin, David Hamilton Martin, Marvin Kent Moss, Jae Young Park, Richard Roland Patty

Study in physics leading to the degrees Master of Science and Doctor of Philosophy is available. Courses, staff, and facilities are provided for presentation of the fundamental subject matter of physics and for specialized study and research in several areas, as listed below:

(a) Nuclear Physics: Theoretical and experimental work in the fields of low energy charged-particle physics, neutron physics, and the statistical behavior of nuclear processes.
(b) Space Physics: Research on phenomena in the upper atmosphere and interplanetary space.
(c) Plasma Physics: Studies of basic ionic processes and applications to thermonuclear research.
(d) Infrared Studies: Research on transmission of radiation through planetary atmospheres and spectroscopic investigations of molecular and solid-state structures.
(e) Lasers: Theoretical and experimental work on the irradiation of laser crystals, and studies relating to new laser materials.
(f) Theoretical Physics: Theory of fields, non-inertial systems, nuclear structure and interactions, plasmas, molecular spectroscopy, and solid state.

Recommended programs of study with emphasis on fundamental physics or on nuclear science leading to the Master of Science degree are available. A minimum of 30 semester credits is required, which is to include 4 credits for research and 2 for seminar. Research and presentation of a thesis are required. Graduates are prepared for college teaching and for research and development activity in general physics or in the space, missile, and energy conversion programs of our country.

The Doctor of Philosophy degree is granted on successful completion of examinations, independent research, and the submission of a dissertation. A minor in mathematics or other area in science is normally elected.

All graduate students and staff are expected to attend a weekly departmental colloquium at which topics of current interest in physics are discussed.

Extensive laboratory facilities are available for research in the areas of specialization. These facilities include:

(a) A 1-mev Van de Graaff accelerator with pulsing equipment for study of neutron scattering, polarization, and diffusion.
(b) A hypersonic ionic wind tunnel for study of simulated space environments.
(c) Fully equipped laboratories (supported by a glass blowing and tube making facility) for the investigation of the stability of ionic streams and the measurement of plasma phenomena by ultrasonic methods.
(d) Laboratories for research in magneto-optical effects, radiation detection, radiation dosimetry, and laser research.
(e) Laboratories for infrared spectroscopy and studies of synthetic planetary atmospheres.
(f) The IBM 1410 Tape System, located in the Computing Center, is available for use in research by graduate students. The Computing Center also offers non-credit short courses in FORTRAN programming.

The Department of Physics participates in the Nuclear Science and Engineering Fellowship program of the Atomic Energy Commission, and Fellowships in Health Physics are currently available under a continuing grant from the U. S. Public Health Service. Students are also eligible for fellowships from the Ford Foundation, the National Science Foundation, and others. Research assistantships are available supported by grants or contracts with federal agencies, and a number of openings for halftime teaching assistantships in general and intermediate physics is available each year.

Research work on nuclear chain reacting systems and on the attenuation of nuclear radiation in matter is conducted cooperatively with the Department of Nuclear Engineering. Research in biophysics is done cooperatively with the Institute of Statistics.

Courses for Advanced Undergraduates

PY 407. Introduction to Modern Physics **3-3**
Prerequisites: PY 207 or PY 208, MA 202
A survey of the important developments in atomic and nuclear physics of this century. Among topics covered are: atomic and molecular structure, determination of properties of ions and fundamental particles, the origin of spectra, ion accelerators, and nuclear reactions.

PY 410. Nuclear Physics I **4-4**
Prerequisite: PY 407
An introduction to the properties of the nucleus, and the interaction of radiation with matter. A quantitative description is given of natural and artificial radioactivity, nuclear reactions, fission, fusion, and the structure of simple nuclei.

PY 411, PY 412. Mechanics **3-3**
Prerequisites: PY 207 or PY 208, MA 301
A sequence of courses in intermediate theoretical mechanics, including the dynamics of particles and rigid bodies, gravitation, moving reference systems, and the physics of continuous media. An introduction is given to advanced mechanics, including D'Alembert's Principle and Lagrange's equations of motion, with applications. Two hours of lecture, and a laboratory or problem period each week.

PY 413. Thermodynamics and Kinetic Theory **0-3**
Prerequisite: PY 207 or PY 208, MA 301
An intermediate course in the principles of classical thermodynamics and the kinetic theory of gases with an introduction to statistical mechanics. Topics covered include equations of state, entropy, Maxwellian distributions, transport processes, and the statistics of Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac. Two hours of lecture, and a laboratory or problem period each week.

PY 414, PY 415. Electricity and Magnetism **3-3**
Prerequisite: PY 207 or PY 208
Corequisite: MA 441
An intermediate course in the fundamentals of static and dynamic electricity and electromagnetic theory, developed from basic experimental laws. Vector

methods are introduced and employed throughout the course. Two hours of lecture, and a laboratory or problem period each week.

PY 416. Optics **3-0**
Prerequisite: PY 415
An intermediate course in physical and geometrical optics with the major emphasis on the wave properties of light. Two hours of lecture, and a laboratory or problem period each week.

PY 499. Special Problems in Physics **1 to 3 - 1 to 3**
Prerequisite: Permission of Department
Study and research in special topics of classical and modern physics. Experimental measurements with emphasis on the treatment and interpretation of data, literature surveys, or theoretical investigations.

Courses for Graduates and Advanced Undergraduates

PY 501. Wave Mechanics **0-3**
Prerequisites: PY 407, MA 441, and either PY 411 or PY 414
An introduction to the foundations of quantum and wave mechanics, with solutions of the problems of the free particle, harmonic oscillator, rigid rotating molecule, and the hydrogen atom. Approximation methods are developed for more complex atomic systems. Mr. Cobb.

PY 503. Introduction to Theoretical Physics **3-0**
Prerequisites: PY 412, PY 414, MA 441
An introductory course in theoretical physics which offers preparation for graduate study. Emphasis is on classical mechanics, special relativity, and the motion of charged particles. Topics which are covered include the variational principles of mechanics, Hamilton's equations, canonical transformations, Hamilton-Jacobi theory, and the theory of small vibrations.
Mr. Moss.

PY 507. Advanced Atomic Physics **3-0**
Prerequisites: PY 412, PY 415, MA 441
A study of atomic structure and spectra, with emphasis on the analysis of spectra. Topics include: the alkali spectra, multiplet structure, electron spin, hyperfine structure, moments. Mr. Cobb.

PY 508. Ionization in Gases **3-0**
Prerequisite: PY 414
Statistical theory of particles, excitation and ionization in gases; mobilities and conductivities; processes at solid surfaces in ionized gases; characteristic forms of electrical discharges in gases. Mr. Bennett.

PY 509. Plasma Physics **0-3**
Prerequisite: PY 508
Individual and collective motion of charged particles in electric and magnetic fields and through ionized gases. Pinch effect, relativistic streams, conductivities, and runaway electrons. Astrophysical concepts and approximations. Properties of plasmas, including waves, confinement, instabilities and shocks, with applications. Mr. Bennett.

PY 510. Nuclear Physics II **4-0**
Prerequisite: PY 410
The description and analysis of nuclear energy levels, meson theory, nuclear

resonance, atomic and molecular magnetism, and cosmic radiation. Principles and experiments in neutron physics are discussed. In the laboratory work, emphasis is placed on gaining experience in independent research.
Mr. Waltner.

PY 514, PY 515. Advanced Electricity and Magnetism **3-3**
Prerequisite: PY 415
An advanced treatment of electricity and magnetism and electromagnetic theory. Topics include: techniques for the solution of potential problems; development of Maxwell's equations; wave equations; energy, force, and momentum relations of an electromagnetic field; covariant formulation of electrodynamics; radiation from accelerated charges. Mr. Katzin.

PY 518. Radiation Hazard and Protection **3-3**
Prerequisite: PY 410
Principles of radiation dosimetry and radiation dose units. Radiation hazards to man. Maximum permissible levels of exposure to external and to internal sources of radiation. Methods of providing protection. Graduate Staff.

PY 520. Physical Measurements in Radioactivity **3-3**
Prerequisite: PY 410
The principles of experimental measurements on radioactive materials are presented and demonstrated through laboratory work. Emphasis is placed on the analytical interpretation of experimental data. Mr. Lynn.

PY 552. Introduction to the Structure of Solids **0-3**
Prerequisite: PY 407
Corequisite: PY 501
Basic considerations of crystalline solids, metals, conductors, and semi-conductors. Mr. Doggett.

PY 555. (See MA 555. Principles of Astrodynamics)

PY 599. Senior Research **3-3**
Prerequisite: Senior Honors Program Standing, Except with Special Permission
Investigations in physics under the guidance of staff members. Literature reviews, experimental measurements, or theoretical studies. A project report is required. Graduate Staff.

Courses for Graduates Only

PY 601, PY 602. Theoretical Physics **3-3**
Prerequisites: PY 503, PY 514
Corequisite: MA 661
Mathematical and theoretical approach to the relationships between various branches of physics. The restricted theory of relativity, electrodynamics, the theory of electrons, classical field theory, and the general theory of relativity are treated. Mr. Davis.

PY 610. Advanced Nuclear Physics **0-3**
Prerequisite: PY 510
Corequisite: PY 611
A theoretical study of nuclear structure and reactions. Topics include: the

deuteron, low-energy nucleon-nucleon scattering, nuclear forces, nuclear moments, nuclear shell theory, collective model, compound nucleus, optical model, and direct reactions. Mr. Park.

PY 611. Quantum Mechanics **3-0**
Prerequisites: PY 501, MA 512
Theory of quantum mechanics with applications to atomic and molecular structure, scattering phenomena, and a semi-classical treatment of the interaction of radiation with matter. Mr. Davis.

PY 612. Advanced Quantum Mechanics **0-3**
Prerequisites: PY 601, PY 611
Dirac's relativistic electron theory, elementary scalar and vector meson field theory. Introduction to quantum electrodynamics and the general theory of quantized fields. Mr. Davis.

PY 620. (See NE 620. Nuclear Radiation Attenuation.)

PY 621. Kinetic Theory of Gases **3-0**
Prerequisites: PY 501, PY 503, MA 512
The theory of molecular motions, including velocity and density distribution functions; the phenomena of viscosity, heat conduction, and diffusion; equations of state; fluctuations. Graduate Staff.

PY 622. Statistical Mechanics **0-3**
Prerequisites: PY 413, PY 503
Corequisite: PY 611
A treatment of classical and quantum statistical mechanics with some applications to thermodynamics. Topics include: statistics of Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein, canonical ensembles and grand canonical ensembles, ideal Fermi gas, and cooperative phenomena.
Mr. Park.

PY 641. Non-Inertial Space Mechanics **0-3**
Prerequisites: PY 601, MA 661
Corequisite: PY 602
The theoretical description of the phenomena of mechanics relating to non-inertial frames of reference with emphasis on applications to space travel and the instrumentation problems of rocketry. Applications to inertial guidance and electromagnetic-inertial coupling effects are also considered.
Mr. Davis.

PY 695. Seminar **1-1**
Reports on topics of current interest in physics. Several sections are offered so that students with common research interests may be grouped together.
Graduate Staff.

PY 699. Research **Credits by Arrangement**
Graduate students sufficiently prepared may undertake research in some selected field of physics. Graduate Staff.

DEPARTMENT OF PLANT PATHOLOGY

Graduate Faculty

Professors: Don Edwin Ellis, *Head,* *Jay Lawrence Apple, Robert Aycock, Carlyle Newton Clayton, Frank Arlo Haasis, Teddy Theodore Hebert, Arthur Kelman, George Blanchard Lucas, Lowell Wendell Nielsen, Charles Joseph Nusbaum, Nash Nicks Winstead

Professor Emeritus: Samuel George Lehman

Associate Professors: William Earl Cooper, Charles S. Hodges, Jr., David M. Kline, Richard Robert Nelson, Nathaniel T. Powell, John Paul Ross, Joseph Neal Sasser, Robert T. Sherwood, Hedwig Hirschmann Triantaphyllou

Visiting Professor: Frederick Lovejoy Wellman

Assistant Professors: Robert Donald Milholland, David Lewis Strider

Adjunct Assistant Professor: Guy Vernon Gooding, Jr.

The department is equipped with laboratory and greenhouse facilities for graduate study in plant pathology including special equipment for all phases of phytopathological research. The State's wide range of soil types and climatic areas make possible the commercial production of a variety of field, vegetable, fruit, and ornamental crops as well as forest trees. Especially favorable opportunities exist for training in diseases caused by nematodes, viruses, fungi, and bacteria which affect many crops. Land and facilites for experimental work are available at some sixteen permanent research stations located throughout the State. Student participation in the Plant Disease Clinic provides excellent training and experience in the diagnosis of all types of plant diseases.

Many opportunities for employment in research, extension, and teaching are available to persons with the Master of Science or Doctor of Philosophy degree in plant pathology. There are openings for qualified persons in plant pathology research in the United States Department of Agriculture, State Experiment Stations and in industry. Opportunities exist in foreign service through international and federal organizations as well as commercial production enterprises. The rapid development of agricultural chemicals for disease control offer numerous opportunities in research, promotion, and service activities.

Courses for Graduates and Advanced Undergraduates

PP 500. Advanced Plant Pathology **0-2**
Prerequisite: PP 315 or Equivalent
An advanced study of the economic importance, symptoms, disease cycles, epiphytology and control of major groups of plant diseases. Students who register for this course are also required to register for either PP 501 or PP 502, or they may register for both. Mr. Winstead.

PP 501. Advanced Plant Pathology Laboratory-Field Crops Diseases **0-1**
Prerequisite: PP 315 or Equivalent
Laboratory course for students whose major interest is diseases of field crops to accompany lecture course in Advanced Plant Pathology (PP 500).

*On leave until November, 1965

Diseases will be selected for study which are important on field crops. Either this course or PP 502 must be taken concurrently with PP 500.

Mr. Kline.

PP 502. Advanced Plant Pathology Laboratory-Horticultural Crop Diseases 0-1
Prerequisite: PP 315 or Equivalent
Laboratory course for students whose major interest is in diseases of horticultural crops to accompany lecture course in Advanced Plant Pathology (PP 500). Diseases will be selected for study which are important on fruit, ornamental and vegetable crops. Either this course or PP 501 must be taken concurrently with PP 500. Mr. Winstead.

PP 503. Disgnosis of Plant Diseases Summer School 3
Prerequisites: One Advanced Course in Plant Pathology and Permission of Instructor
A study of techniques used in plant disease diagnosis with emphasis on diagnostic value of signs and symptoms for certain types of diseases. Consideration will be given to major sources of descriptive information on plant pathogens and the use of keys for the identification of fungi. (Offered summer 1964 and in alternate years.) Mr. Hebert.

Courses for Graduates Only

PP 601. Phytopathology I 4-0
Prerequisites: PP 315 and Permission of Instructor
A study of the principles of phytopathological research. The course is designed to apply the classical scientific method to disease investigation. Exercises will include appraising disease problems, reviewing literature, laboratory and greenhouse experiments and the evaluation and presentation of data. Mr. Apple.

PP 602. Phytopathology II 0-4
Prerequisites: PP 315 and Permission of Instructor
The basic concepts of the etiology, pathology, epiphytology and control of plant diseases. Mr. Nusbaum.

PP 604. Plant Parasitic Nematodes 2-0
Prerequisite: PP 315
A study of morphology, anatomy, physiology and taxonomy of plant parasitic nematodes. Methods of isolating nematodes from soil and plant parts and other laboratory techniques used in the study and identification of nematodes will be considered. Mrs. Triantaphyllou.

PP 605. Plant Virology 3-0
Prerequisites: PP 315, GN 411, A Course in Organic Chemistry
A study of plant viruses including effects on host plants, transmission, classification, methods of purification, determination of properties, chemical nature, structure and multiplication. (Offered 1965-66 and in alternate years.) Mr. Hebert.

PP 607. (GN 607) Genetics of Fungi 3-0
Prerequisites: GN 512, or Equivalent and Permission of Instructor
Review of major contributions in fungus genetics with emphasis on principles and theories that have evolved in recent developments. (Offered 1964-65 and in alternate years.) Mr. Nelson.

PP 608. History of Phytopathology **1-0**
Prerequisites: PP 315 and Permission of Instructor
Development of the science of phytopathology from its early beginnings to the early part of the 20th century. (Offered 1965-66 and in alternate years.)
Mr. Ellis.

PP 609. Current Phytopathological Research Under Field Conditions **0-2**
Prerequisite: Graduate Standing
Study of concepts involved, procedures used, and evaluation made in current phytopathological research by Plant Pathology staff. Visits to various Research Stations will be made by the class. Mr. Clayton.

PP 611. Nematode Diseases of Plants **0-3**
Prerequisite: PP 604
A study of plant diseases caused by nematodes. Special consideration will be given to host-parasite relationships, host ranges and life cycles of the more important economic species. Principles and methods of control will be considered. Mr. Sasser.

PP 612. Plant Pathogenesis **3-0**
Prerequisites: PP 500 and Permission of Instructor
A study of interactions of pathogens and suscept plants. The following major topics will be considered: hydrolytic enzymes, polysaccharides, and toxins in wilting phenomena; mode of action of toxins in altering plant metabolism; role of growth regulators in hypertrophic responses; alterations in respiration and other physiological processes during pathogenesis; and nature and biochemical basis for disease resistance. (Offered 1964-65 and in alternate years.) Mr. Kelman.

PP 690. Seminar in Plant Pathology **1-1**
Prerequisite: Consent of Seminar Chairman
Discussion of phytopathological topics selected and assigned by seminar chairman. Mr. Nielsen.

PP 699. Research in Plant Pathology **Credits by Arrangement**
Prerequisites: Graduate Standing and Consent of Instructor
Original research in Plant Pathology. Graduate Staff.

U.N.C. BO 211, BO 212. Advanced Mycology **5-5**
Prerequisite: U. N. C. 42 or BO 101 or Equivalent
Phycomycetes, Ascomycetes, Basidiomycetes and Fungi Imperfecti. These courses are intended for students who plan to specialize in Mycology, Plant Pathology, and Biology. Classwork consists of lectures and student reports on literature. Laboratory work consists of the collection and identification of fungi and the study of their structure and development, and techniques for isolation and pure culture. (Two hours of lecture and four hours of laboratory each week.) Mr. Couch.

DEPARTMENT OF POULTRY SCIENCE

Graduate Faculty

Professors: Henry Wilburn Garren, *Head,* Clifford Warren Barber, Frank Rankin Craig, Edward Walker Glazener, Charles Horace Hill, Jr., Morley Richard Kare, Joseph Wheeler Kelly
Associate Professors: William Lowry Blow, Freeman Waldo Cook
Assistant Professors: William E. Donaldson, Robert E. Lubow

The Department of Poultry Science offers graduate study leading to the Master of Science degree in poultry science with major emphasis in either genetics, nutrition or physiology. Arrangements also exist whereby Ph.D. candidates can be directed by certain staff members of this department. Students accepted for graduate study must present evidence of scholastic achievement in the basic biological sciences.

The Department of Poultry Science occupies Scott Hall. This building contains well equipped research laboratories, animal rooms, library and offices. Additional research facilities are located on the University poultry farms and on three outlying farms in the western, Piedmont and eastern sections of North Carolina. The research program is comprehensive and ranges from fundamental biochemical, physiological and genetic investigations to applied agricultural problems.

Many opportunities, both domestic and foreign, exist for graduates with advanced training. These include teaching and research positions in public and private educational institutions, Civil Service, and industry. Graduates can expect to find employment in areas of basic biological science and public health as well as agriculture. The demand for men and women with advanced training is far greater than the supply.

Courses for Advanced Undergraduates

PO 401. Poultry Diseoses **0-4**
Prerequisites: Required of Majors in Poultry Science. Elective for Others with Permission of the Instructor
The prevention, control, and treatment of the diseases of poultry.

PO 402. Commercial Poultry Enterprises **0-4**
Prerequisites: Required of Majors in Poultry Science. Elective for Others with Permission of the Instructor
Principles of incubation, hatchery management, development and organization of plans for the building, operation, and maintenance of a commercial poultry plant. (Problem.)

PO 403. Poultry Seminar **1-1**
Prerequisite: Required of Majors in Poultry Science, Senior Year
Topics and problems relating to Poultry Science and Poultry Industry assigned for report and discussion.

Courses for Graduates and Advanced Undergraduates

PO 520. Poultry Breeding **3-0**
Prerequisites: GN 411, Required of Majors in Poultry Science; Elective for Others with Permission of the Instructor

Application of genetic principles to chickens and turkeys, considering physical traits and physiological characteristics—feather patterns, egg production, hatchability, growth, body conformation, and utility. (Laboratory problems.) Mr. Martin.

PO 521. Poultry Nutrition **3-0**
Prerequisites: CH 203, CH 451. Required of Majors in Poultry Science; Elective for Others
Protein, vitamin, and mineral requirements for growth, egg production, and reproduction in the chicken and turkey. Methods of feeding and compounding poultry mashes. Laboratory exercises in the production of vitamin and mineral deficiencies. Mr. Kelly.

PO 524. (ZO 524) Comparative Endocrinology **0-3**
Prerequisite: ZO 301 or Equivalent
Study of the endocrine system with respect to its physiological importance to metabolism, growth, and reproduction. Mr. Garren.

Courses for Graduates Only

PO 602. Advanced Poultry Nutrition **3 or 3**
Prerequisites: PO 521, CH 551 or Equivalent
Research problem in poultry nutrition involving the design and carrying out of microbiological and chick experiments. Results from microbiological and chick assays are correlated. Mr. Hill.

PO 698. Special Problems in Poultry Science **Maximum 6**
Prerequisite: Graduate Standing
Specific problems using advanced technology for theory exploration.
Graduate Staff.

PO 699. Poultry Research **Credits by Arrangement**
Prerequisite: Graduate Standing in Poultry Science
Critical study of some particular problem involving original investigation. (A maximum of six credits is allowed toward the Master's degree.)
Graduate Staff.

DEPARTMENT OF PSYCHOLOGY
(See School of Education)

DEPARTMENT OF RURAL SOCIOLOGY

Graduate Faculty

Professors: Selz Cabot Mayo, *Head,* Edgar John Boone, Charles Horace Hamilton
Associate Professors: Culpepper Paul Marsh, *Glenn C. McCann, James Neal Young

The Department of Rural Sociology offers the Master of Science and the Doctor of Philosophy degrees.

Graduate students studying for the Doctor of Philosophy degree usually take approximately one semester of course work in the Department of

* On leave until July 1965.

Sociology at the University of North Carolina at Chapel Hill. Students seeking the Master of Science degree may take courses at Chapel Hill. However, they will be able to complete their entire program at North Carolina State.

The physical and educational resources of the Rural Sociology Department, available to graduate students, include a departmental library of bulletins, monographs, and other materials consisting of several thousand items, accumulated over a period of thirty years, and catalogued in indexed files. Laboratory equipment consists of calculating machines, drawing table and instruments, chart making materials, cameras, typewriters, and statistical aids. Also at the disposal of the graduate students are automobiles used for making field surveys and IBM tabulating equipment operated by the Computing Center.

The Department of Rural Sociology prepares graduate students for a variety of positions. Men and women with graduate degrees in rural sociology have opportunities for careers in college teaching, socological research, social statistics, social work, administration of social organzations and governmental agencies, agricultural journalism, and in branches of the government's foreign service relating to agriculture and the developing areas of the world.

Institutions offering employment to graduates are Land-Grant colleges, agricultural experiment stations, and extension services; other colleges and universities; the United States Departments of Agriculture, State, and Health, Education and Welfare; state departments of health, education and welfare; farm journals and newspapers, and voluntary social agencies such as Red Cross, Community Chest, Boy Scouts, and National Tuberculosis Association. Each year outstanding graduate students are awarded research or teaching assistantships, usually requiring the devotion of half of their time to a research project or teaching function as appropriate. Cooperative research work in the department frequently provides opportunities for part-time employment for other graduate students.

Courses for Graduates and Advanced Undergraduates

RS 511. Rural Population Problems **3-0**
Prerequisite: RS 301
A study of population growth, rates of change, and distribution. Considerable attention is given to the functional roles of population, i.e., age, sex, race, residence, occupation, marital status, and education. The dynamic aspects of population are stressed: fertility, mortality, and migration. Population policy is analyzed in relation to national and international goals. A world view is stressed throughout. Mr. Mayo.

RS 512. Rural Family Living **0-3**
Prerequisite: RS 301
Values, patterns, and levels of rural family living. Differentials and factors related thereto in the world, the nation, and North Carolina. Analysis of selected problems, programs, policies, and methods of study.
Mr. Hamilton.

RS 513. Community Organization **3-0**
Prerequisite: RS 301
Community organization is viewed as a process of bringing about desirable

changes in community life. Community needs and resources available to meet these needs are studied. Democratic processes in community action and principles of community organization are stressed, along with techniques and procedures. The roles of leaders, both lay and professional, in community development are analyzed. Mr. Mayo.

U.N.C. Philo. 107. Foundations of the Social Sciences **0-3**
Prerequisites: Two Courses in Philosophy, Psychology or Sociology
An inquiry into the nature of social reality through an examination of the basic concepts of sociology, history, etc. Behavioral and subjective approaches are contrasted. Both methodological and more broadly philosophical problems are discussed. Mr. Natanson.

U.N.C. Anthro. 121. Culture and Personality **0-3**
A scientific analysis of the influence of cultural forms on the individual in our own and other societies, considered from the anthropological, psychological, and clinical points of view. (Offered in the spring of 1965-66 and in alternate years.) Mr. Honigmann.

U.N.C. Soc. 122. Cultural Anthropology **3-0**
A systematic survey of the customs and modes of life of mankind based on scientific explanation of the ways of culture. Fee: $1.00. Fall.
Mr. Johnson.

U.N.C. Soc. 125. The Negro **0-3**
A study of the Negro community and its institutions, status of the Negro in American society, problems of race relations, and the process of integration. Spring. Mr. Johnson.

U.N.C. Soc. 128. Folk Cultures in the Modern World **0-3**
The folk culture is viewed as a way of life which stands midway between that of the "primitive" tribal native and of the urbanized city dweller. Fee: $1.00. (Offered in 1965-66 and alternate years.) Mr. Erasmus.

RS 523. Sociological Analysis of Agricultural Land Tenure Systems **3-0**
Prerequisite: Three Hours of Sociology
A systematic sociological analysis of the major agricultural land tenure systems of the world with major emphasis on the problems of family farm ownership and tenancy in the United States. Mr. Johnson.

RS 534. (HI 534) The Farmers' Movement **0-3**
Prerequisite: Three Hours of Sociology
A history of agricultural organizations and movements in the United States and Canada principally since 1865, emphasizing the Grange, the Farmers' Alliance, the Populist revolt, the Farmers' Union, the Farm Bureau, the Equity societies, the Nonpartisan League, cooperative marketing, government programs, and present problems. Mr. Noblin.

U.N.C. Soc. 152. History of Social Thought **3-0**
Prerequisite: One Course in One of the Social Sciences or Philosophy
Emphasis on historic social ideas of Western culture considered against a background of general cultural analysis in terms of systematic theory.
Mr. Vance.

U.N.C. Soc. 153. Social Structure **3-0**
Analysis of social structure and stratification in terms of class, status, prestige, rank, and function. Attention is given to the social role of the elite, bureaucracies, and professional and middle classes. Mr. Vance.

U.N.C. Soc. 161. Sociology of the Family **0-3**
Analysis of the family institution as a background for the study of family interaction: socialization and the parent-child relationship, courtship and marriage interaction, family crises and problems. Mr. Bowerman.

RS 541. Social Systems and Planned Change **3-0**
Prerequisite: Three Hours of Sociology
Study of social agencies and programs and their implementation through specific organizations in dynamic relation with the people whom they serve. Consideration is given to the relation of these agencies and programs to community structure and forces in rural society; coordination of the several types of agencies and programs; professional leadership in the local community; and, problems of stimulating local leadership and participation.
Mr. Mayo.

U.N.C. Soc. 168. The City **0-3**
The city as a social phenomenon in the modern world. Analysis of urban trends, characteristics, and functions; urban social organization. Sociological elements in housing, urban planning, and metropolitan dominance. Growth patterns in new centers of urbanization. Mr. Campbell.

U.N.C. Religion 170. Sociology of Religion **0-3**
Analysis of tensions between the scientific, ethical, and theological study of society; the role of religion in social change; the social origins of the denominations; the sociological significance of the Reformation; "sect" and "church" in sociological theory. Mr. Nash.

U.N.C. Soc 181. Regional Sociology of the South **0-3**
A sociological analysis of the southern region of the United States. Emphasis on fact, factors, and policies pertaining to geography, population and culture; resources and waste; social institutions and planning.
Mr. Simpson.

Courses for Graduates Only

U.N.C. Soc. 210. Folk Sociology **3-0**
Folk sociology as a subject field for the historical study of total human society and the empirical study of group behavior. Mr. Simpson.

RS 611. Research Methods in Sociology **3-0**
Prerequisite: Six Hours of Sociology
Designed to give the student a mature insight into the nature of scientific research in sociology. Assesses the nature and purpose of research designs, the interrelationship of theory and research, the use of selected techniques and their relation to research designs, and the use of modern tabulation equipment in research. Mr. McCann.

U.N.C. Soc. 212. American Sociologists **0-3**
A general treatise on the rise and development of American sociology and a survey of the work and personalities of American sociologists projected on the background of social theory and research. Mr. Simpson.

U.N.C. Soc. 218. Human Ecology (Seminar) **0-3**
Consideration of theory and research emerging around the concept of human ecology. A review of the background of human ecology is followed by readings, reports, and research on its contemporary development. (Offered in 1964-65 and alternate years.) Mr. Vance.

U.N.C. Anthro. 220. Theories of Culture **0-3**
A systematic survey of the history in cultural anthropology leading to the development of a system of operational principles which the student may apply in his own fieldwork and further studies involving cultural problems. (Offered in 1965-66 and alternate years.) Mr. Honigmann.

RS 621. Rural Social Psychology **3-0**
Prerequisite: Six Hours of Sociology
Treats the genetic development of the rural personality and the interrelationship of the individual and the rural society. Studies of social psychological factors related to rural leadership, morale, social organization, and social change, and examines the attitudes and opinions of rural people on current local and national issues. Mr. McCann.

U.N.C. Anthro. 221. Field Methods in Cultural Anthropology **0-3**
Practical exercises and discussion cover topics of role taking, observation, interviewing, note taking, and pattern generalization. Mr. Honigmann.

U.N.C. Anthro. 230. Race and Culture Contacts **0-3**
An analysis of acculturation situations arising from contracts of peoples of different racial or cultural heritages in America, Africa, Polynesia, Melanesia, and other areas. Mr. Johnson.

RS 631. Population Analysis **0-3**
Prerequisite: Six Hours of Sociology
Methods of describing, analyzing, and presenting data on human populations: distribution, characteristics, natural increase, migration, and trends in relation to resources. Mr. Hamilton.

RS 632. Rural Family **3-0**
Prerequisite: Six Hours of Sociology
Emphasis is placed on the development of an adequate sociological frame of reference for family analysis; on discovering both the uniquely-cultural and common-human aspects of the family by means of cross-cultural comparisons; on historical explanations for variability in American families with special concern for the rural family; and on analyzing patterns of family stability and effectiveness. Mr. Hamilton.

RS 633. The Rural Community **0-3**
Prerequisite: Six Hours of Sociology
The rural community is viewed in sociological perspective as a functioning entity. A method of analysis is presented and applied to eight "dimensions", with emphasis on the unique types of understanding to be derived from measuring each dimension. Finally, the effect of change on community integration and development is analyzed. Mr. Mayo.

U.N.C. Soc. 262. European Sociological Theory **3-0**
Theory in sociological research. Major methodological and theoretical orientations. Development from European backgrounds of current theories of differentiation, integration, change, social systems and structural-functional analysis. Mr. Simpson.

U.N.C. Soc. 333. Seminar in Marriage and the Family **3-0**
Mr. Bowerman.

U.N.C. Soc. 334. Critique of Research in Marriage and the Family **3-0**
This seminar reviews the basic conceptual frameworks used in family re-

search in the past; identifies changing emphasis in family study; and evaluates current studies in the major fields of family research. (Offered in 1964-65 and alternate years.) Mr. Bowerman.

U.N.C. Psych. 233. Methods of Investigation in Social Psychology 0-3
Methods of investigation in psychology with application to the social sciences. Survey methodology with particular emphasis on techniques, contributions, and limitations of public opinion polling. Mr. Thibaut.

RS 641. (ST 641) Statistics in Sociology 3-0
Prerequisite: Statistics 513
The application of statistical methods of sociological research. Emphasis on selecting appropriate models, instruments, and techniques, for the more frequently encountered problems and forms of data. Mr. Hamilton.

RS 652. Comparative Rural Societies 3-0
Prerequisite: Six Hours of Sociology
Sociological analysis of rural societies around the world with particular reference to North and South America. Special emphasis is given to cultural and physical setting, population composition, levels of living, relationship of the people to the land, structure and function of the major institutions, and forces making for change. Mr. Mayo.

RS 653. Theory and Development of Rural Sociology 0-3
Prerequisite: Six Hours of Sociology
Required of all masters and doctoral candidates in rural sociology and is recommended for all graduate minors. Designed to meet two objectives: (1) to introduce the student to the study of current sociological theory, and (2) to survey events and trends in the historical development of rural sociology. Mr. Hamilton.

RS 690. Seminar Credits by Arrangement
Appraisal of current literature; presentation of research papers by students; progress reports on departmental research; review of developing research methods and plans; reports from scientific meetings and conferences; other professional matters. (A maximum of two credits is allowed toward the Master's degree, and four credits toward the Doctorate.)

RS 699. Research in Rural Sociology Credits by Arrangement
Prerequisite: Permission of Chairman of Graduate Study Committee
Planning and execution of research, and preparation of manuscript under supervision of graduate committee. (Maximum of six credits.) Staff.

DEPARTMENT OF SOCIOLOGY AND ANTHROPOLOGY

Graduate Faculty

Professors: Selz Cabot Mayo, *Head,* Elmer Hubert Johnson, Sanford Richard Winston
Associate Professor: Horace Darr Rawls

The Department of Sociology and Anthropology cooperates with the Department of Rural Sociology in programs of study leading to graduate degrees. In addition, courses are available to students pursuing a graduate program in other areas of study.

Courses for Advanced Undergraduates

SOC 401. Human Relations in Industrial Society **3 or 3**
Prerequisite: Senior Status or Permission of Instructor
Selected societies about the world are contrasted with American society to demonstrate the correlation between technology and general behavior patterns, both within industry and in the total social order. The patterns of adjustment by the individual to the organizational framework (business concern, manufacturing enterprise, etc.) are analyzed in terms of social status, social roles, work norms, and attitudes. The social significance of major characteristics of contemporary industry is considered in terms of such topics as enlargement of the geographic bounds of the human community, development of occupational specialization, alteration of the character of inter-group interaction, and the growing integration of American culture. The interrelationships between industry and social change are discussed to show the effect of new social conditions upon industrial operations and the effect of technological change upon the family, school, church, and government. The contribution of industry to social progress is analyzed to promote the student's understanding of the dynamic quality of the social environment within which he will function.

SOC 402. Urban Sociology **3 or 3**
Prerequisites: SOC 202 and Permission of Instructor
The course begins with a study of the factors behind the organic growth of cities. The relationship between the physical design of cities and their social organization is discussed. This is followed by a detailed analysis of new developments in the serving of human needs (adequate housing, and the design of physical and social structures for religious, educational, public welfare, and recreational activities). Socio-psychological aspects of life in an urbanized society are compared with those of predominantly agricultural societies. The increasing integration of urban and rural living is emphasized. Finally, the changing character of urban life is seen in the resulting demand for city and regional planning and the use of administrative personnel having both technical and social backgrounds.

SOC 411. Community Relationships **3 or 3**
Prerequisites: SOC 202 and Permission of Instructor
A survey of the institutions, organizations, and agencies to be found in modern communities; the social conditions or problems, such as recreation, health, welfare, etc., with which they deal; their inter-relationship and the trend toward over-all planning.

SOC 412. Introduction to Social Work **3 or 3**
Prerequisites: SOC 202 and Permission of Instructor
An introductory course, designed to acquaint students with the various types of public and private social work and with remedial and preventive programs in applied sociology; social psychiatry, health, public welfare, and recreation.

SOC 414. Social Structure **3 or 3**
Prerequisites: Six Hours in Sociology and Permission of Instructor
Studies of the major social institutions and systems of stratification; the

organization of social systems as, for example, religion, education, and government; the functions of such structural components as age and sex groups, vocational and professional groups, and social classes.

SOC 416. Research Methods **3 or 3**
Prerequisites: Nine Hours in Sociology and Permission of Instructor
An analysis of the principle methods of social research; the development of experiments; schedules and questionnaires; the measurement of behavior.

Courses for Graduates and Advanced Undergraduates

SOC 501. Leadership **3 or 3**
Prerequisites: SOC 202, SOC 301, or Equivalent
A study of leadership in various fields of American life: analysis of the various factors associated with leadership; techniques of leadership. Particular attention is given to recreational, scientific, and executive leadership procedures. Mr. Winston.

SOC 502. Society, Culture, and Personality **3 or 3**
Prerequisites: SOC 202, SOC 301, or Equivalent
Human personality is studied from its origins in primary groups through its development in secondary contacts and its ultimate integration with social norms. While comparative anthropological materials will be drawn upon, emphasis is placed upon the normal personality and the adjustment of the individual to our society and to our culture. The dynamics of personality and character structure are analyzed in terms of the general culture patterns and social institutions of society. Mr. Rawls.

SOC 505. The Sociology of Rehabilitation **3 or 3**
Prerequisites: SOC 202, SOC 301, or Equivalent
The course stresses the social and cultural implications of the rehabilitation approach. Emphasis is placed upon the social and personal problems of physically and mentally handicapped persons. The interrelationships of the major social environments are considered at length in this regard. Objectives of the rehabilitation processes are analyzed in terms of the sociology of work. A major portion of the course is devoted to rehabilitation as a profession, particular attention being given to the diverse roles of specialists in this field. Mr. Rawls.

SOC 511. Sociological Theory **3 or 3**
Prerequisites: Six Semester Hours in Sociology and Graduate Standing or Permission of the Instructor
Study of the interdependence of theory and method; the major theoretical and methodological systems; and examination of selected cases of research in which theory and method are classically combined. Mr. Rawls.

SOC 510. Industrial Sociology **3 or 3**
Prerequisites: SOC 202, SOC 301, or Equivalent
Industrial relations are analyzed as group behavior with a complex and dynamic network of rights, obligations, sentiments, and rules. This social system is viewed as an interdependent part of total community life. The background and functioning of industrialism are studied as social and cultural phenomena. Specific social problems of industry are analyzed.
Mr. Johnson.

SOC 590. Applied Research **3 or 3**
Prerequisites: SOC 202, SOC 301, or Equivalent
Individual research problems in applied fields of sociology, such as problems of the family, population, and social work; rural-urban relations; student success; American leadership. Graduate Staff.

DEPARTMENT OF SOIL SCIENCE

Graduate Faculty

Professors: Ralph J. McCracken, *Head,* William Victor Bartholomew, James Walter Fitts, Eugene J. Kamprath, James Fulton Lutz, Charles B. McCants, William Garland Woltz, William Walton Woodhouse, Jr.

Associate Professors: Charles Bingham Davey, William A. Jackson, Preston Harding Reid, James Maurice Spain, Richard J. Volk, Sterling B. Weed

Assistant Professors: Maurice Gayle Cook, George A. Cummings, Robert E. McCollum, Raymond Jarvis Miller

The Department of Soil Science offers training leading to the degrees of Master of Science and Doctor of Philosophy with major emphases in the fields of soil chemistry, soil fertility, soil physics, soil genesis, and soil microbiology.

Facilities are provided for soils graduate teaching and research in Williams Hall, a large modern building. Office and laboratory space is assigned to each student. A library equipped with books, periodicals and biographic material relative to soils and related subjects is maintained for departmental use. Facilities for graduate study include radioactive and stable isotope laboratories containing automatic recording scalers, a mass spectrometer, amino acid analyzer, complete equipment for soil mineralogical studies including x-ray diffraction apparatus with fluorescence, differential thermal analysis, infrared spectrophotometer, polarizing microscope, high speed centrifuges, thin sectioning apparatus, and other modern equipment. Photomicrographic equipment is available for photographing thin sections and microorganisms.

Service laboratories for routine soil and plant analyses are available as well as special preparation rooms for soil and plant samples. Greenhouses and growth chambers situated at the back of Williams Hall are accessible for controlled plant studies. Outdoor experiments in concrete frames, large tile, or small plots are conducted in an area near Williams Hall. Field experiments are made on the sixteen research farms owned or operated by the State. These farms are located throughout North Carolina to include a wide variety of soil and climatic conditions needed for experiments in soils. One of the largest and best equipped soil testing laboratories in the United States is operated by the North Carolina Department of Agriculture in Raleigh. Special studies on the various problems of soil testing can be made in conjunction with this laboratory.

Strong supporting departments greatly increase the graduate student's opportunities for a broad and thorough training. Included among those de-

partments in which graduate students in soil science work cooperatively or obtain instruction are crop science, botany, chemistry, geology, mathematics, plant pathology, physics, and statistics.

Courses for Graduates and Advanced Undergraduates

SSC 511. Soil Physics **4-0**
Prerequisites: SSC 200, PY 212
Physical constitution and analyses; soil structure, soil water, soil air and soil temperature in relation to plant growth. Mr. Lutz.

SSC 522. Soil Chemistry **0-4**
Prerequisites: SSC 200, SSC 553 and CH 433 or Permission of Instructor
A consideration of the chemical and colloidal properties of clay and soil systems, including ion exchange and retention, soil solution reactions, solvation of clays, and eletrokinetic properties of clay-water systems.
Mr. Weed.

SSC 524. Mass Spectrometry **0-2**
Prerequisites: SSC 302 and CH 433 or Permission of Instructor
An examination of theoretical and analytical aspects of mass spectrometry and stable isotopic techniques; application of these methods to biochemical research. (Offered 1964-65 and in alternate years.) Mr. Volk.

SSC 532. (BO 531) Soil Microbiology **0-3**
Prerequisites: SSC 302, BO 312, CH 220
The more important microbiological processes that occur in soils; decomposition or organic materials, ammonification, nitrification, and nitrogen fixation. Mr. Bartholomew.

SSC 541. Soil Fertility **3-0**
Prerequisites: SSC 302, SSC 341
Soil conditions affecting plant growth and the chemistry of soil and fertilizer interrelationships. Factors affecting the availability of nutrients. Methods of measuring nutrient availability. Mr. Kamprath.

SSC 551. Soil Morphology, Genesis and Classification **3-0**
Prerequisites: SSC 200, SSC 302 or SSC 341 and MIG 120
Morphology: Study of concepts of soil horizons and soil profiles and chemical, physical and mineralogical parameters useful in characterizing them. Genesis: Critical study of soil forming factors and processes. Classification: Critical evaluation of historical development and present concepts of soil taxonomy with particular reference to great soil groups as well as discussion of logical basis of soil classification. Mr. McCracken.

SSC 553. Soil Mineralogy **3-0**
Prerequisites: SSC 200, SSC 341 and MIG 330 or Permission of Instructor
Composition, structure, classification, identification, origin, occurrence, and significance of soil minerals with emphasis on primary weatherable silicates, layer silicate clays, and sesquioxides. Messrs. McCracken, Weed.

SSC 560. North Carolina Soils and Their Management **Summer School 3**
Prerequisites: SSC 200, SSC 302 or SSC 341
Field studies of selected soil series in the Coastal Plain, Piedmont and Mountain areas of North Carolina. Discussion of management practices

that should be associated with the various soils under different types of farming. (Offered 1965 summer and in alternate years.)
Messrs. Fitts, McCracken, Spain.

SSC 590. Special Problems **Credits by Arrangement**
Prerequisites: SSC 200, SSC 302
Special problems in various phases of soils. Problems may be selected or will be assigned. Emphasis will be placed on review of recent and current research. Staff.

Courses for Graduates Only

SSC 622. Physical and Chemical Properties of Soils **0-4**
Prerequisites: SSC 511, SSC 522, CH 433, MA 301 or Permission of Instructor
An examination in depth of current ideas concerning the physics and chemistry of soil and clay systems. Topics will include ion exchange, molecular adsorption, electrokinetics, relations between mineral structures and their physical and chemical properties, and the properties of adsorbed water. Emphasis will be determined by student interest and by current literature. (Offered 1964-65 and in alternate years.) Messrs. Miller, Weed.

SSC 651. Pedology **3-0**
Prerequisites: SSC 522, SSC 511
A critical study of current theories and concepts in soil genesis and morphology; detailed study of soil taxonomy. Topics include weathering and clay mineral genesis as related to soil morphology and genesis, functional analyses of soil genesis, properties of and processes responsible for soil profiles formed under various sets of soil forming factors, classification theory and logic as applied to soil classification, structure of soil classification schemes. Any of those topics may be emphasized at the expense of the others according to interests of students. (Offered 1965-66 and in alternate years.)
Mr. McCracken.

SSC 672. Soil Properties and Plant Development **0-4**
Prerequisites: CH 551, SSC 522 or Equivalent
A detailed examination of the effects of soil factors in the development of crop plants. Segments of the course will treat (1) soil transformation processes of both organic and inorganic constituents, (2) concepts of nutrient availability and (3) the relation of plant development indices to specific soil properties. (Offered 1965-66 and in alternate years.)
Messrs. Bartholomew, Davey, Jackson.

SSC 690. Seminar **1-1**
Prerequisite: Graduate Standing in Soil Science
Scientific articles, progress reports in research and special problems of interest to agronomists reviewed and discussed. (A maximum of two credits is allowed toward the Master's degree, but any number toward the Doctorate.)
Graduate Staff.

SSC 699. Research **Credits by Arrangement**
Prerequisite: Graduate Standing in Soil Science
A maximum of six credits is allowed toward the Master's degree, but any number toward the Doctorate. Graduate Staff.

SCHOOL OF TEXTILES

Graduate Faculty

Professors: Malcolm Eugene Campbell, *Dean,* Clarence Monroe Asbill, Jr., John Francis Bogdan, Kenneth Stoddard Campbell, David Marshall Cates, Elliot Brown Grover, Dame Scott Hamby, Harley Young Jennings, Joseph Alexander Porter, Jr., Henry Ames Rutherford, William Edward Shinn

Associate Professors: Arthur A. Armstrong, Jr., Arthur Courtney Hayes, William Clifton Stuckey, Jr.

Assistant Professor: Ernest Bezold Berry

Post Doctoral Research Instructors: Ilham A. Birkan, Joachim Gayler

The School of Textiles offers programs leading to the Master of Science in Textile Technology, Master of Textile Technology, and Master of Science in Textile Chemistry.

The fundamental objectives of the graduate program in the School of Textiles are to develop in students their abilities to initiate and conduct independent investigations which lead to the development of new knowledge, and to stimulate the thought processes associated with learning and decision making. These objectives are accomplished through programs designed to increase the general knowledge of the student and to develop a more comprehensive understanding of the major field through study and research.

The program of study for the graduate student in Textile Technology may be arranged to develop a broad background in advanced technology and, at the same time, emphasize areas such as fiber and yarn technology, fabric technology, knitting technology, or quality control. In addition to the major field of Textile Technology, students may minor in fields such as experimental statistics, economics, mathematics, physics, engineering, psychology, and political science.

The programs of study for the Master of Science degree include a minimum of 30 semester credit hours of advanced courses, a thesis based on research conducted by the student, and proficiency in one foreign language. The plan of course work and the research activities for the Master of Science degree are designed to prepare the student for a career in research, quality control, and other technical phases of the textile industry, as well as a continuation of his educational program to more advanced degrees. The minimum requirement for a Master of Textile Technology is the satisfactory completion of 36 semester credit hours of advanced courses. There is no thesis or foreign language requirement for the Master of Textile Technology. The basic purpose of this program is to offer to the student the more advanced technology without the emphasis on research. Students studying for this degree are encouraged to minor in economics with emphasis in the area of management.

In the Department of Textile Technology the current activities in research include such problems as fundamental studies of man-made fiber properties, characterization of combed and carded yarns, influence of variation in linear density of in-process materials as related to finished product quality, and processing problems as associated with the newest developments in materials and supplementary equipment.

In the Department of Textile Chemistry research emphasis is placed on absorption studies, textile chemical processes, new materials and new methods, and modification of fibrous polymers. The objective of the graduate program is to stimulate basic research and to train scientists at the graduate level in the general field of fiber chemistry. Strong supporting programs are maintained in chemistry, chemical engineering, mathematics, experimental statistics, and physics.

The physical resources of the School of Textiles are at the disposal of all graduate students. Separate research laboratories for both physical and chemical investigations are available for graduate research. The research and educational programs of the school have facilitated the development of a competent staff of instructors and researchers. A shop is available in Nelson Textile Building for construction and maintenance of apparatus.

A number of teaching assistantships and research fellowships are available. The stipend ranges from $1,800 to $2,700 with some fellowships also including tuition and fees.

The demand by industry and educational institutions for graduates with advanced degees has constantly exceeded the supply. The financial remuneration is not only larger, but professional development and recognition are generally more readily attained.

Courses for Advanced Undergraduates

Textile Technology

TX 430. Continuous Filament Yarns **3-3**
Prerequisite: TX 303
Required of students in Fiber and Yarn Technology and Knitting Technology; Elective for Others
A study of properties and processes applicable only to filament yarns such as texturizing and bulking. Detailed studies of throwing systems, engineering requirements of equipment, and yarn property changes resulting from processing. (Two 1-hour lectures and one 2-hour laboratory period per week.)

TX 436. Staple Fiber Processing **3-3**
Prerequisite: TX 303
Required of Students in Fiber and Yarn Technology; Elective for Others
A study of special systems of processing long, staple, natural and man-made fibers, including woolen, worsted, direct spinning, Turbo Stapler, or Pacific Converter, and sliver to yarn methods. New concepts and research findings as applied to all yarn processes. (Two 1-hour lectures and one 2-hour laboratory period per week.)

Textile Chemistry

TC 403, TC 404. Textile Chemical Technology **3-3**
Prerequisites: TC 304, CH 223
Required of seniors in Textile Chemistry
Basic principles are applied to the study of three important areas of textile processing; dyeing, printing, and finishing. These areas are concerned with

the chemical nature of dyes and other chemical agents applied to fibrous systems; with the chemical and physical properties of the various fibers; and with the mechanical aspects of the application of chemical materials to fibers and fabrics. The course includes an extensive review of the various classes of dyes and their application to all important textile fibers and blends of fibers; a comparative analysis of dyeing machinery and processes involving special machinery and equipment; a survey of modern preparatory and bleaching for all important fibers; a study of the roller printing machine, and the principles involved in print formulations for the major classes of dyes and their application to the various fibers; a study of important mechanical, additive, and chemical modification type finishes for fabric. Three 1-hour lectures per week. Mr. Campbell.

TC 405, TC 406. Textile Chemical Technology Laboratory **2-2**
Required of seniors in Textile Chemistry
To be taken concurrently with TV 403 or 404. Two 3-hour laboratories per week.

TC 412. Textile Chemical Analysis II **3-0**
Prerequisite: CH 215
Required of Students in Textile Chemistry
Analysis of textile materials involving specialized instruments, and techniques such as spectrophotometry, pH measurements, electrometric titration, viscometry, etc. (One 1-hour lecture and two 3-hour laboratories per week.)

TC 421. Fabric Finishing I **0-2**
Prerequisite: TC 201
Students in Textile Chemistry may not take this course for degree credit. A general course in fabric finishing designed for students not majoring in Textile Chemistry. Emphasis placed on finishes used on garment-type fabrics, including stabilization finishes, water repellency, crease resistance, moth and mildew proofing, fire-proofing, etc. Emphasis on chemistry of finishes varied to fit requirements of students. (Two 1-hour lectures per week.)

General Textile Courses

TX 483. Textile Cost Methods **3-3**
Prerequisites: TX 303, TX 365
Required of Seniors in Textiles except those in Management Option
A survey of cost methods applicable to textile operations with emphasis on decision making as related to costing and cost control. (Three 1-hour lectures per week.)

Knitting Technology

TX 441. Flat Knitting **3-0**
Prerequisite: TX 342
Required of Seniors in Knitting Technology; Elective for Others
A study of the leading types of flat knitting machines including warp knitting machines, design possibilities and fabric adaptability. (Two 1-hour lectures and one 2-hour laboratory per week.)

TX 442. Knitted Fabrics **3-3**
Prerequisite: TX 342
Required of Seniors in Textile Technology and Knitting Technology
Design, analysis, and production of knitted fabrics, including flat, circular, and warp types. The economic aspects of the knitting process as a method of clothing production. Introduction to garment design, production and marketing. (Two 1-hour lectures and one 2-hour laboratory period per week.)

TX 444. Garment Manufacture **0-3**
Prerequisite: TX 342
Required of Seniors in Knitting Technology; Elective for Others
A study of circular latch needle and spring needle machines for knitted fabric production. Styling, cutting and seaming of the basic garment types for underwear and outerwear, standard seam types; high-speed sewing machines. (Two 1-hour lectures and one 2-hour laboratory period per week.)

TX 447, TX 448. Advanced Knitting Laboratory **2-2**
Prerequisite: TX 342
Required of Seniors in Knitting Technology; Elective for Others
Systematic study of circular hosiery mechanisms; hosiery types and constructions. Seamless hosiery production methods utilizing the newer synthetic yarns, toe closing methods, finishing processes, and marketing are emphasized.

TX 449. Tricot Knitting **0-3**
Prerequisite: TX 342
Elective for Juniors and Seniors
A study of basic types of tricot knitting machines with emphasis on mechanisms and fabrics. Attention is given to warp preparation methods applicable to the tricot machine, the characteristics of yarn made from natural and synthetic fibers as they affect processing into warp knitted fabrics, machine settings for proper qualities and ratios; economics of warp knitting, and end uses. Attention is given to fabric design and analysis. (Two 1-hour lectures and one 2-hour laboratory period per week.)

TX 478. Design and Weaving **3-3**
Prerequisite: TX 366
Required of Students in Fabric Technology; Elective for Others
Advanced study of special weave formations and the techniques and equipment necessary to form these fabrics. Studies in depth of new developments and research findings in the areas of warp preparation, design, weaving and fabric formation. (Two 1-hour lectures and one 2-hour laboratory period per week.)

TX 485. Mill Design and Organization **3-3**
Prerequisites: TX 303, TX 365
Required of Students in Textile Technology Curriculum; for Seniors in Final Semester Only
Application of economic principles to textile factoring, hedging, and other buying and selling problems. Inventory control, organization, and departmental functions of textile companies. Technical problems of plant site

selection, plant design and layout, and selection of equipment. Layout of a mill by each student. (Two 1-hour lectures and one 2-hour laboratory period per week.)

TX 490. Development Project I **Credits by Arrangement**
Prerequisite: Senior Standing and Permission of Instructor; Elective
A problem of independent study assigned to seniors in the major field of study serving also as the laboratory period for senior level courses. (Laboratory hours arranged.)

Courses for Graduates and Advanced Undergraduates

Textile Technology

TX 501. Textile Technology Seminar **2-2**
Prerequisite: Senior Standing and Permission of Instructor; Elective
Lecture and discussion periods are designed for students who are particularly interested in the yarn manufacturing aspects of the textile industry. Subject matter will include such various aspects as training methods, safety programs, modern mill design, specialized techniques in setting rates, employee relations, and developments that arise from technical meetings. (Two 1-hour lectures per week.) Mr. Grover, Gradute Staff.

TX 521. Textile Testing II **3-0**
Prerequisite: TX 327
Elective
Advanced techniques for measuring properties of natural and man-made fibers, yarns, and fabrics. Interrelations of raw material quality, processing characteristics, and end product properties. The application of the laws of physical sciences to evaluation of textile materials. (Two 1-hour lectures and one 3-hour laboratory per week.) Messrs. Hamby, Stuckey.

TX 522. Textile Quality Control **0-3**
Prerequisite: TX 521
Elective
Quality control systems for textile operations. Defect prevention methods, isolation of processes contributing to substandard quality, relationship between quality control department and operating division. Laboratory design, equipment and personnel selection, installation of quality control systems. (Two 1-hour lectures and one 3-hour laboratory period per week.) Messrs. Hamby, Stuckey.

TX 525. Advanced Textile Microscopy **2-2**
Prerequisite: TX 327
Elective
Experiments, lectures and demonstrations in more advanced techniques of textile microscopy. Detailed studies of structures of fibers covered in lecture series, supplemented by experiments on lecture topics. Detailed study of all types of microscopes and their uses in textiles. Preparation of slides for photography. Uses of photomicrographic equipment. Lectures and laboratories arranged. Mr. Stuckey.

TX 551. Complex Woven Structures **4-4**
Prerequisites: TX 303, TX 478
Elective
The development of design specifications for complex fabrics as related to fabric geometry, functional and aesthetic properties and manufacturing limitations. (Three 1-hour lectures and one 2-hour laboratory per week.)
Mr. Berry.

TX 575. Fabric Analytics and Characteristics **3-3**
Prerequisite: TX 365 or TX 366 or TC 511
Analysis and study of textile fabrics to determine the composite effects of yarn and fiber properties. Fabric design features that are related to mechanical as well as aesthetic properties. Engineering and fabrics based on utilization of other mixtures and homogeneous blends of natural and man-made fibers. (Three 1-hour lectures per week.)
Messrs. Berry, Porter.

TX 590. Special Projects in Textiles **1 to 3**
Prerequisites: TX 327, Senior Standing, Permission of Instructors, Elective
Special studies in either the major or minor field of the advanced undergraduate or graduate student. These special studies will take the form of current problems of the industry, independent investigations in the areas of textile testing and quality control, seminars and technical presentations, both oral and written. Staff.

Textile Chemistry

TC 501. Seminar in Textile Chemistry **0-2**
Prerequisite: TC 403
Required of Seniors in Textile Chemistry
The course is designed to familiarize the student with the principal sources of textile chemical literature and to emphasize the importance of keeping abreast of developments in the field of textile chemistry. Particular attention is paid to the fundamentals of technical writing. (Reports. Lectures arranged.) Mr. Campbell, Staff.

TC 512. (CH 512) Chemistry of High Polymers **0-3**
Prerequisite: CH 431
Elective
Principles of condensation and free radical polymerization; kinetics and molecular wright description; copolymerization and composition; emulsion polymerization; structure. (Three 1-hour lectures per week.) Mr. Cates.

TC 521. Textile Chemical Analysis III **3-3**
Prerequisite: TC 421 or Permission of Instructor
Elective for Students in Textile Technology; No Credit Allowed for Students Majoring in Textile Chemistry
The work includes a survey of organic chemistry, with emphasis on organic surfactants, warp sizes, and fabric finishes of all types; the identification of fibers by chemical means; the qualitative and quantitative analysis of fiber blends by chemical means, the identification of finishes; the evaluation techniques for dyed and finished materials. (Two 1-hour lectures and one 3-hour laboratory period per week.) Staff.

TC 561. (CH 561) Chemistry of Fibers **3-0**
Prerequisite: CH 223
Required of Seniors in Textile Chemistry
A lecture course emphasizing the theory of fiber structure; the relationship between the chemical structure and physical properties of natural and man-made fibers; the nature of the chemical reactions which produce degradation of fibers; the production of man-made fibers. (Three 1-hour lectures per week.) Mr. Rutherford.

General Textiles

TX 581. Instrumentation and Control **3-3**
Prerequisite: PY 212
Required of All Seniors in Textiles and Textile Chemistry
A lecture series with coordinated laboratory exercises designed to familiarize the student with the theory and application of instruments and control apparatus that he will find in the modern textile plant. The studies cover the measurement and control of temperature, humidity, pressure, flow and liquid level, the application of control apparatus to chemical processes and physical finishing of textile products. (Two 1-hour and one 2-hour laboratory period per week.) Mr. Asbill.

Courses for Graduates Only

TX 601, TX 602. Yarn Technology **3-3**
Prerequisite: Graduate Standing
Studies of advanced techniques in textile production; the technological aspects of fiber properties in relation to processing; studies of research findings and application of these to processing equipment.
Messrs. Grover, Hamby.

TC 605. Physical Chemistry of Dyeing **3-3**
Prerequisite: CH 433
Development of principles of thermodynamics, emphasizing applications in dye and fiber chemistry. Mr. Cates.

TC 606. Chemistry of Fiber-Forming High Polymers **3-0**
Prerequisite: CH 431
Structure and properties of fibers; thermodynamics of sorption and solution; solution properties; molecular weight determination; flow properties; mechanical properties. (Three 1-hour lectures per week.)
Mr. Cates.

TX 621. Textile Testing III **2-2**
Prerequisite: TX 522 or Equivalent
Design of textile laboratories, including conditioning equipment and instruments required for specific needs: performance of tests and analysis of data on industrial problems; specialized physical tests; inter-laboratory tests and analysis; study of A.S.T.M. specifications and work on task groups for the A.S.T.M. Society. Mr. Hamby.

TX 631. Synthetic Fibers **0-2**
Prerequisite: TX 430 or TX 436 or Equivalent
Lectures and projects on advanced problems relative to the properties and processing of man-made continuous filament and staple fiber yarns.
Messrs. Grover, Hamby.

TX 641, TX 642. Advanced Knitting Systems and Mechanisms **3-3**
Prerequisite: TX 441 or Equivalent
A critical study of inventions which have contributed to the development of the modern knitting industry; knitting needles and their adaption for specific uses; means for mounting them for individual and en masse operation; construction and functioning of cooperating elements including sliders, jacks, sinkers, dividers, pressing elements, narrowing and tensioning and draw-off motions, regulating mechanisms, timing and control chains and cams. Use will be made of patent literature which covers important developments in the hosiery industry. (Three 1-hour lectures per week.)
Mr. Shinn.

TX 643, TX 644. Knitting Technology **3-3**
Prerequisites: Graduate Standing and Eight Credits in Knitting Technology
Problems of specific interest to the knitting industry will be assigned for study and investigation. The use of experimental methods will be emphasized. Attention will be given to the preparation of reports for publication.
Graduate Staff.

TX 651, TX 652. Fabric Development and Construction **3-3**
Prerequisite: Graduate Standing
Application of advanced technology to the development and construction of woven fabrics. Mr. Porter.

TX 698. Seminar **1-1**
Discussion of scientific articles of interest to textile industry; review and discussion of student papers and research problems.
Graduate Staff.

TX 699. Textile Research **Credits by Arrangement**
Problems of specific interest to the textile industry will be assigned for study and investigation. The use of experimental methods will be emphasized. Attention will be given to the preparation of reports for publication. The master's thesis may be based upon the data obtained.
Graduate Staff.

DEPARTMENT OF ZOOLOGY

Graduate Faculty

Professors: Bernard Stephen Martof, *Head,* Frederick Schenck Barkalow, Jr., Daniel Swartwood Grosch, Reinard Harkema, Don William Hayne, Morley Richard Kare, Ralph Winston Stacy, Thomas Lavelle Quay
Professor Emeritus: Bartholomew Brandner Brandt
Adjunct Professor: Theodore R. Rice
Associate Professors: William Walton Hassler, Francis Eugene Hester, Grover Cleveland Miller, John Anthony Santolucito
Assistant Professors: Charles Walter Alliston, Robert E. Lubow

The Department of Zoology offers to qualified students the opportunity to earn the Master of Science and the Doctor of Philosophy degrees. Students

may specialize in many areas: behavior, general ecology, population dynamics, limnology, fisheries biology, wildlife biology, the taxonomy, ecology and life histories of parasites, comparative morphology and systematics of vertebrates, comparative and developmental physiology, endocrinology, sensory physiology, and the dynamics of respiration and circulation.

The department is located in Gardner Hall where facilities for a wide variety of research activities are available. Several ponds and pools near Raleigh are used for graduate studies as are certain parks and recreation areas. A research station is available at Hatteras for studies in marine and estuarine fisheries; additional field facilities occur in the Roanoke River, Albemarle Sound and Chowan River areas.

By mutual agreement, a student may choose to do his research with any member of the graduate staff. A student will make up his plan of study after discussing his interests and objectives with his major professor and advisory committee. Those courses will be selected which will best prepare him for his particular interests. Advanced courses in other departments provide a variety of subjects for minor fields of study: botany, entomology, genetics, statistics, biochemistry, psychology, and other related sciences. The student is given the opportunity to develop a high order of independent thought, broad knowledge, technical skills, and thorough training in investigative techniques. Strong emphasis is placed on active participation in seminars, practice in the methods of original research and preparation of manuscripts for publication in scientific journals.

A variety of positions are open to students holding advanced degrees. There is a great need for professional zoologists in teaching and research in institutions of higher learning and in industry. Research personnel are especially in demand in behavior, physiology and the paramedical sciences. Numerous positions in the Fish and Wildlife Service, the Soil Conservation Service, the Forest Service, and the Park Service are open to zoologists.

Courses for Graduates and Advanced Undergraduates

ZO 501. Ornithology **0-3**
Prerequisite: BS 100
The biology and classification of birds. Field trips for the study and identification of local forms, including trips to Lake Mattamuskeet in February and the coast in May. Individual research projects on nesting populations.
Mr. Quay.

ZO 513. Comparative Animal Physiology **3-0**
Prerequisite: ZO 301
The comparative physiology of selected systems. Topics will be chosen for detailed consideration in lectures, collateral reading, and class discussion. Each student will, in addition, prepare a term report. A few topics for study may be determined by the interests of the students and by their needs as may be expressed by the supervisor of their major work.
Mr. Santolucito.

ZO 520. Fishery Science **3-0**
Prerequisites: BS 100 and Approval of Instructor
This course is intended as an introduction to the principles and methods of

fishery science. Current theories and practices of fish management will be studied. Life history and biology of important game and commercial species. Survey of fishery resources. Mr. Hassler.

ZO 521. Fishery Science **0-3**
Prerequisite: ZO 520
An analysis of fishery research methods and objectives. Detailed studies of the procedures for estimating fish populations, annual reproduction, mortality rates, growth rates, and exploitation rates. The relationship between natural fluctuations in fisheries and environmental factors. Mr. Hassler.

ZO 522. Animal Ecology **3-0**
Prerequisite: BS 100
The general principles of the inter-relations among animals and between animals and their environments—land, freshwater, marine. Mr. Quay.

ZO 524. (PO 524) Comparative Endocrinology **0-3**
Prerequisite: ZO 301 or Equivalent
Study of the endocrine system with respect to its physiological importance to metabolism, growth, and reproduction. Laboratory techniques and demonstrations. Mr. Garren.

ZO 532. (See GN 532. Biological Effects of Radiations.)

ZO 540. (See GN 540. Evolution.)

ZO 541. Ichthyology **0-3**
Prerequisite: Approval of the Instructor
The classification and ecology of selected groups of fishes. Lectures, laboratories, and field trips dealing with the systematic positions, life histories, interrelationships, and distribution of the particular groups of fishes selected in accordance with the needs and interests of the class. Mr. Hassler.

ZO 542. Herpetology **0-3**
Prerequisite: BS 100
The biology of amphibians and reptiles. Lectures, laboratories, and field trips dealing with systematics, life histories, anatomy, behavior, and ecology. (Offered 1964-65 and alternate years.) Mr. Martof.

ZO 544. Mammalogy **3-0**
Prerequisites: BS 100, ZO 201, and Approval of Instructor
The classification, identification, and ecology of the major mammalian groups. Mr. Barkalow.

ZO 545. Histology **4-0**
Prerequisite: BS 100
The microscopic anatomy of animal tissues. Staff.

ZO 550. (See GN 550. Experimental Evolution.)

ZO 551, ZO 552. Wildlife Science **3-3**
Prerequisite: ZO 201
The principles of wildlife management and their application are studied in the laboratory and in the field. Mr. Barkalow.

ZO 561. Animal Embryology **0-4**
Prerequisite: BS 100
The study of fundamental principles which apply in the achievement of complex animal structure. Mr. Alliston.

ZO 581. Parasitology I **4-0**
Prerequisite: ZO 223
The study of the morphology, biology, and control of the parasitic protozoa and helminths of man, domestic and wild animals. Mr. Harkema.

ZO 582. (ENT 582) Medical and Veterinary Entomology **0-3**
Prerequisite: ENT 301 or ENT 312
A study of the morphology, biology and control of the parasitic arthropods of man, domestic and wild animals. Messrs. Farrier, Harkema.

ZO 590. Special Studies **Credits by Arrangement**
Prerequisite: Approval of Instructor
A directed individual investigation of a particular problem in Zoology, accompanied by a review of the pertinent literature. A maximum of three credits allowed toward the bachelor's degree, six toward the master's degree and nine toward the doctorate. Staff.

Courses for Graduates Only

ZO 603. Advanced Parasitology **0-3**
Prerequisite: ZO 581
The study of the theoretical and practical aspects of parasitism; taxonomy, physiology, and immunology of animal parasites. Mr. Harkema.

ZO 604. (ANS 604) Experimental Animal Physiology **4-0**
Prerequisite: ZO 513 or Equivalent
A study of the theories and techniques involved in the use of animals in physiological investigation. Messrs. Ulberg, Wise.

ZO 614. Cell Physiology **3-0**
Prerequisites: ZO 301 and Approval of Instructor
A study of those fundamental physiological properties at the cellular level which are common to nearly all organisms. Lectures, discussions, and critical reports (oral and written) to promote acquaintance with general literature and recent advances. Mr. Santolucito.

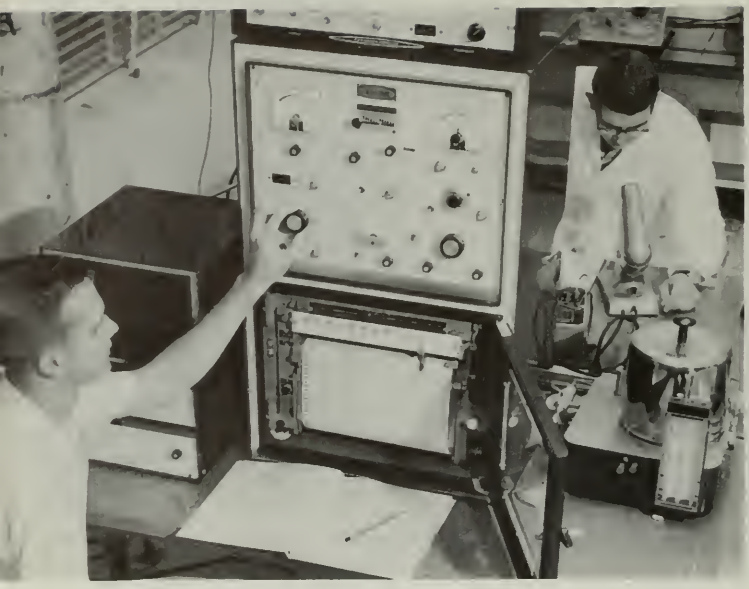
ZO 627. Zoogeography **3-0**
Prerequisites: ZO 522 and Approval of Instructor
The geographic distribution of animals, with primary emphasis on land and fresh-water vertebrates. Mr. Quay.

ZO 690. Seminar **1-1**
The presentation and defense of current literature papers dealing either with the findings of original research or with fundamental biological concepts. Staff.

ZO 699. Research in Zoology **Credits by Arrangement**
Prerequisites: Twelve Semester Credits in Zoology and Approval of Instructor
Original research related to the student's thesis. A maximum of six credits is allowed toward the master's degree, but any number toward the doctorate. Staff.

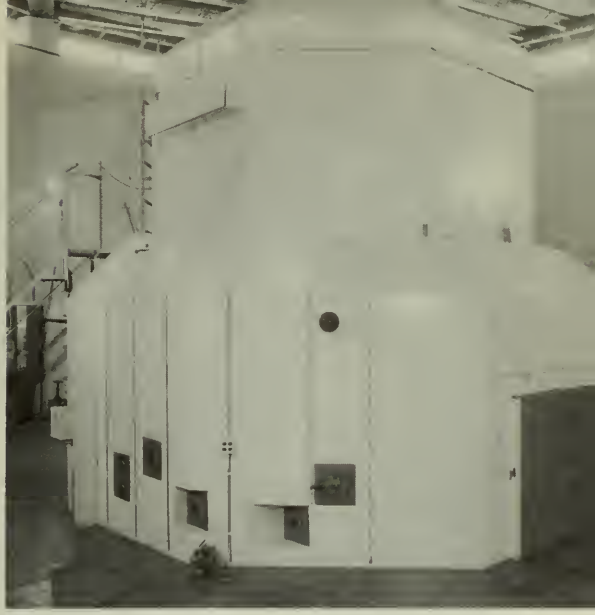
Agricultural Engineering—Human energy requirements under simulated work-loads and environmental variables are given quantitative description.

Chemical engineering and civil engineering graduate students and faculty cooperate on highway research. Recording temperature measurements of test strips on a North Carolina highway is part of the bituminous highway project.



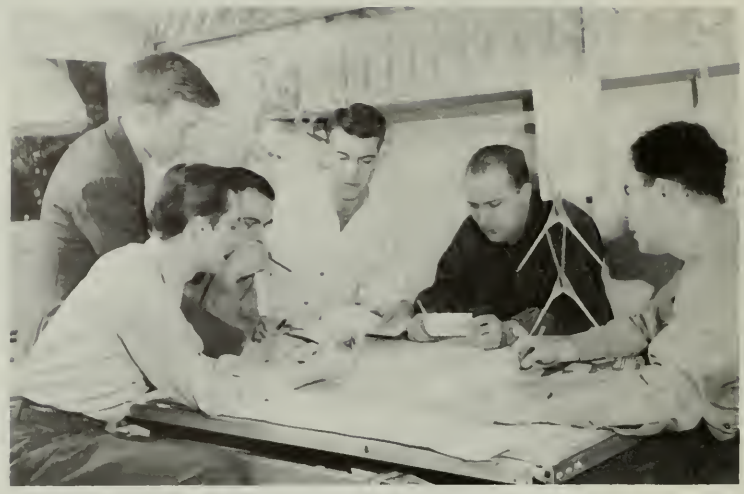
Textiles—Graduate students test a fabric in the Gas Chromatograph, a device for analyzing volatile products arising from thermal decomposition of high polymers. The Gas Chromatograph is just one of many research aids in laboratories of the Department of Textile Chemistry.

Civil Engineering—An experimental study on an aluminum alloy connection of a geodesic dome under axial loads is conducted by a civil engineering professor investigating the stability of connecting elements.



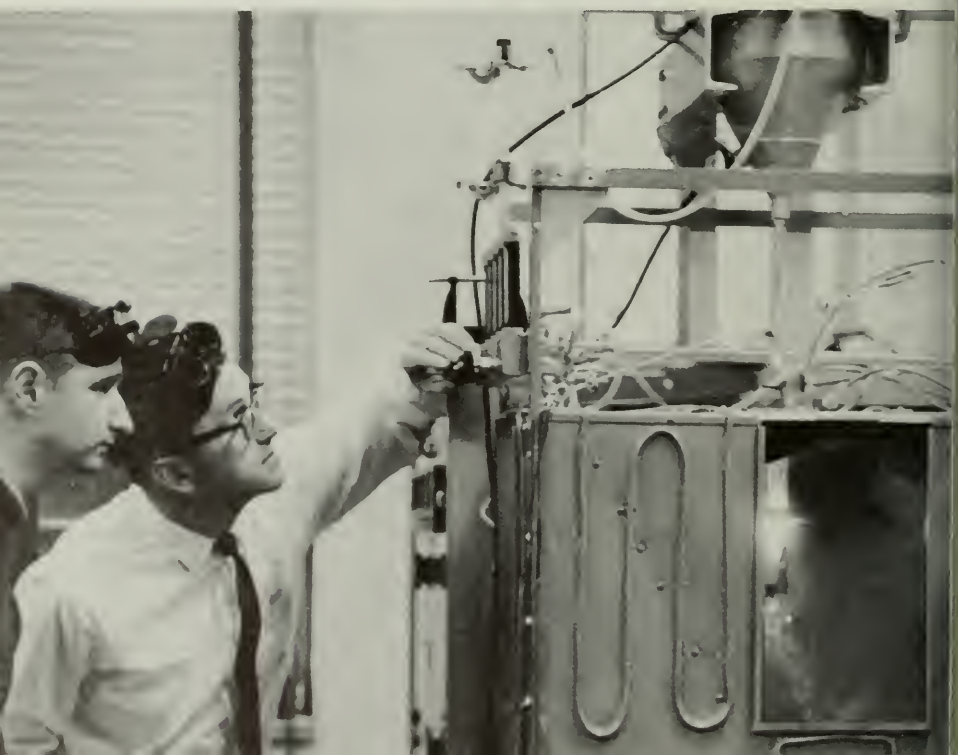
Nuclear Engineering—This imposing concrete form shields State's nuclear reactor, housed in the Burlington Nuclear Laboratories, center for research on peacetime application of atomic energy. State was the first school in the United States to own a nuclear reactor.

Library—Among State's research facilities is the D. H. Hill Library with holdings of ver 279,000 volumes. The library has a well-rounded collection for graduate study. ecent acquisitions reflect increasing campus interest in the liberal arts and strong esearch programs in the fields of science and engineering.



Design—Students work out a problem in structural design. The three departments of the School of Design are located in Brooks Hall.

Engineering Research—The ultra high temperature plasma crystal growing facili is an integral part of the materials research program.

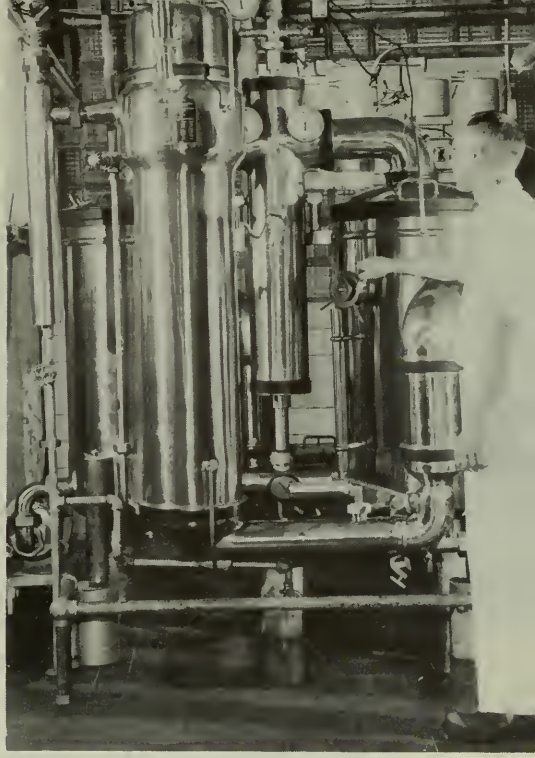


Agricultural Research—Vital to the multi-million dollar agricultural research activities ore the extensive greenhouse facilities for crop and horticulture sciences.

Animal Science—Spacious, well-equipped laboratories offer graduate students excellent opportunity for research and study. Students of animal science frequently use diagnostic laboratories in their course of study.

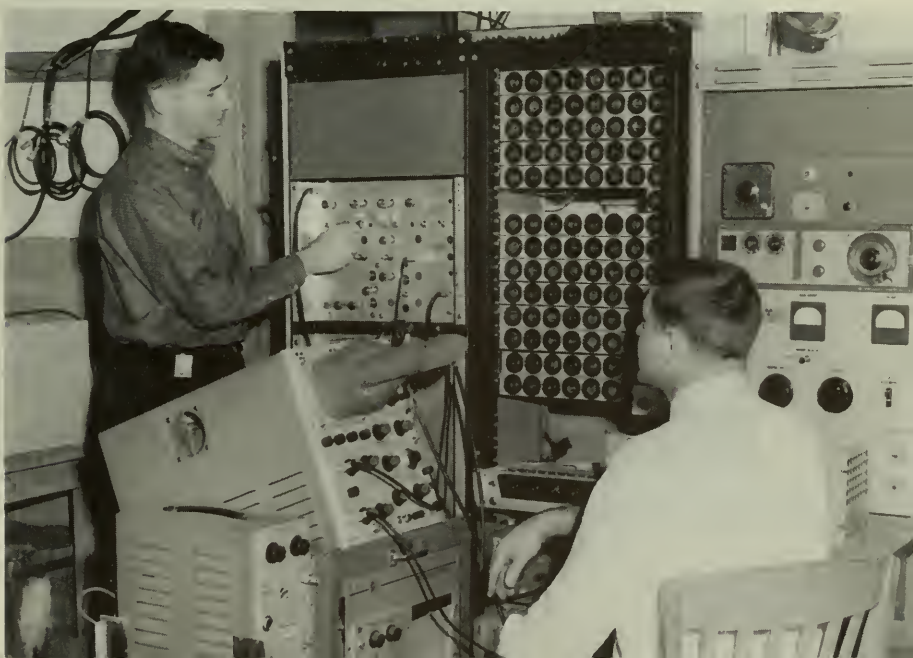
Applied Mathematics—Researchers in applied mathematics employ the intricate machinery of the Goodyear Electronic Differential Analyzer in their work.

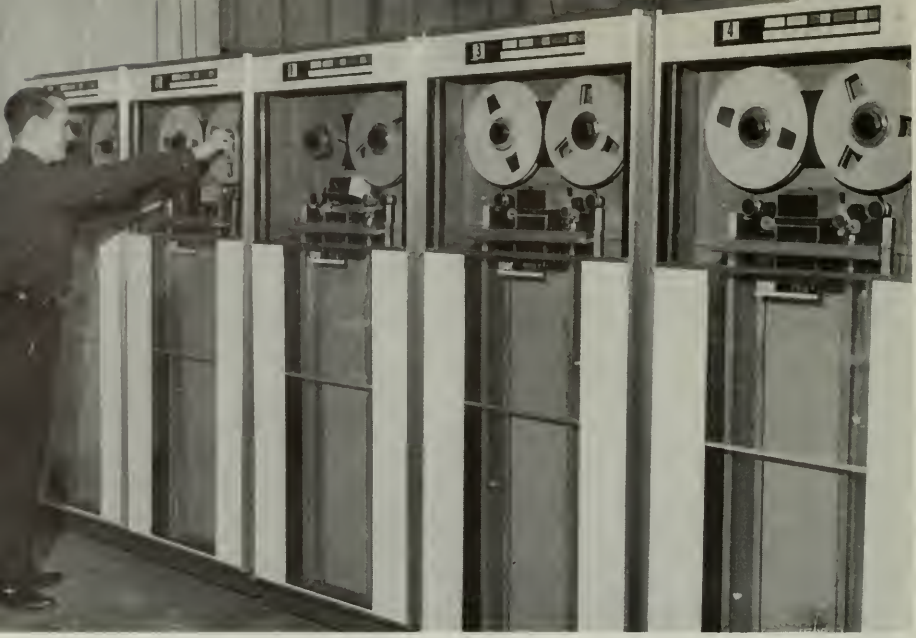
Wood Technology—Research in forestry and wood products is leading to the development of new processes, techniques, and uses for woods. A veneer cutting investigation is made by these students in wood technology.



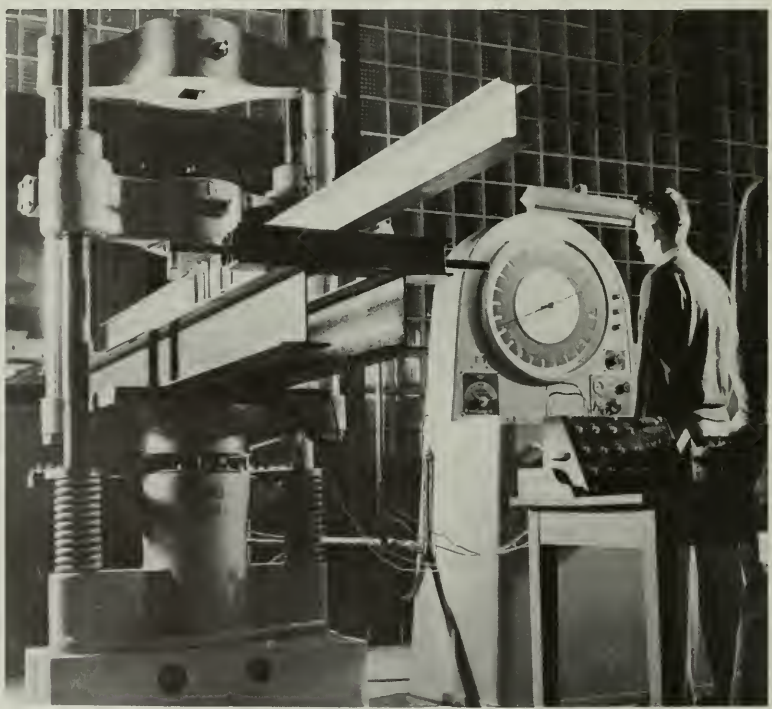
Food Science—The research staff is constantly seeking ways of improving the important dairying industry. Modern facilities, such as this steam-vacuum equipment, is aiding in research to meet the challenge of new products.

Engineering—Research problems frequently call for specialized equipment. Here graduate students in engineering carry out their research with the aid of the Van de Graaff control and instrumentation panel.





Computing Center—The IBM 1410 Tape System provides the computing facility for faculty and students in research and instruction. Two IBM 1620's and a LINC III furnish additional computing capabilities for some departments.



Civil Engineering—Students in a physical testing laboratory conduct stress analysis study on an aluminum beam.

* GRADUATE FACULTY
AT
NORTH CAROLINA STATE
OF
THE UNIVERSITY OF NORTH CAROLINA
AT RALEIGH

Sidney Addelman, Adjunct Assistant Professor of Experimental Statistics.
Ph.D., Iowa State University.

Charles Walter Alliston, Assistant Professor of Zoology.
Ph.D., North Carolina State.

Raul E. Alvarez, Assistant Professor of Industrial Engineering.
M.S., North Carolina State.

Michael Amein, Assistant Professor of Civil Engineering.
Ph.D., Cornell University.

Clifton A. Anderson, Professor of Industrial Engineering and Head of Department.
Ph.D., Ohio State University.

Donald Benton Anderson, Professor of Botany and Vice President of Academic Affairs of The University of North Carolina.
Ph.D., Ohio State University.

Richard Loree Anderson, Professor of Experimental Statistics and Graduate Administrator.
Ph.D., Iowa State College.

Roy Nels Anderson, Professor of Education and Head of Department of Occupational Information and Guidance.
Ph.D., Columbia University.

*Jay Lawrence Apple, Professor of Plant Pathology.
Ph.D., North Carolina State.

Arthur A. Armstrong, Associate Professor of Textile Chemistry.
Ph.D., North Carolina State.

Frank B. Armstrong, Assistant Professor of Genetics and Botany and Bacteriology.
Ph.D., University of California.

Clarence Monroe Asbill, Jr., Professor of Textile Machine Design and Development and Head of Department.
B.S., Clemson College.

Leonard William Aurand, Professor of Food Science.
Ph.D., Pennsylvania State College.

William Wyatt Austin, Jr., Professor of Metallurgical Engineering and Head of Department of Mineral Industries.
Ph.D., Vanderbilt University.

Richard Charles Axtell, Assistant Professor of Entomology.
Ph.D., Cornell University.

Robert Aycock, Professor of Plant Pathology.
Ph.D., North Carolina State.

Thomas Sanderson Baldwin, Assistant Professor of Psychology.
Ph.D., Ohio State University.

Ernest A. Ball, Professor of Botany and Bacteriology.
Ph.D., University of California.

*** Membership in the graduate faculty may be in either of two categories: (1) full status or (2) associate status. Full status permits a faculty member to engage in any and all phases of the graduate programs of the University. Associate members may teach courses at the graduate level and serve as chairman of master's advisory committees.**

*** On leave until November, 1965**

Walter Elmer Ballinger, Associate Professor of Horticultural Science.
Ph.D., Michigan State College.
Clifford Warren Barber, Professor of Poultry Science.
Ph.D. Cornell University.
William John Barclay, Professor of Electrical Engineering.
Ph.D., Stanford University.
Aldos Cortez Barefoot, Jr., Associate Professor of Wood Products.
Doctor of Forestry, Duke University.
Frederick Schenck Barkalow, Jr., Professor of Zoology.
Ph.D., University of Michigan.
Key Lee Barkley, Professor of Psychology.
Ph.D., University of North Carolina.
Elliott Roy Rarrick, Professor of Animal Science and Head of Animal Dairy and Husbandry Section.
Ph.D., Purdue University.
William Victor Bartholomew, Professor of Soil Science.
Ph.D., Iowa State College.
Edward Guy Batte, Professor of Animal Science and Head of Veterinary Section.
D.V.M., Texas A & M.
Ernest Oscar Beal, Associate Professor of Botany and Bacteriology.
Ph.D., State University of Iowa.
Homer Edwin Beam, Assistant Professor of Agricultural Education.
Ed.D., University of North Carolina.
Kenneth Orion Beatty, Jr., Professor of Chemical Engineering.
Ph.D., University of Michigan.
Burton Floyd Beers, Associate Professor of History and Political Science.
Ph.D., Duke University.
Norman Robert Bell, Associate Professor of Electrical Engineering.
M.S., Cornell University.
Thomas A. Bell, Associate Professor of Food Science.
M.S., North Carolina State.
William Callum Bell, Professor of Ceramic Engineering in Engineering Research.
Ph.D., Ohio State University.
Willard Harrison Bennett, Burlington Professor of Physics.
Ph.D., University of Michigan.
Eugene Edwin Bernard, Assistant Professor of Psychology.
Ph.D., University of Leeds.
Ernest Bezold Berry, Assistant Professor of Textiles.
B.S., Clemson College.
Bibhuti Bhushan Bhattacharyya, Assistant Professor of Experimental Statistics.
Ph.D., London School of Economics.
Richard Hugh Bigelow, Associate Professor of Civil Engineering.
M.S., North Carolina State.
Ilham Ahmet Birkan, Research Instructor of Textiles.
Ph.D., Technical University of Istanbul.
John William Bishir, Assistant Professor of Mathematics.
Ph.D., North Carolina State.
Charles Edwin Bishop, William Neal Reynolds Distinguished Professor of Agricultural Economics and Head of Department.
Ph.D., University of Chicago.
William Joseph Block, Professor of History and Political Science.
Ph.D., University of Illinois.

William Lowry Blow, Associate Professor of Poultry Science.
Ph.D., North Carolina State.
Thomas Nelson Blumer, Professor of Food Science.
Ph.D., Michigan State College.
John Francis Bogdan, Professor of Textiles and Director of Processing Research.
B.T.E., Lowell Textile Institute.
Edgar John Boone, Professor of Rural Sociology and Assistant Director of Extension.
Ph.D., University of Wisconsin.
Carey H. Bostian, Professor of Genetics.
Ph.D., University of Pittsburgh.
Henry Dittimus Bowen, Professor of Agricultural Engineering.
Ph.D., Michigan State College.
Lawrence Hoffman Bowen, Assistant Professor of Chemistry.
Ph.D., Massachusetts Institute of Technology.
Charles Raymond Bramer, Professor of Civil Engineering and Acting Head of Department.
E. M., Michigan College of Mining and Technology.
Bartholomew Brandner Brandt, Professor Emeritus of Zoology.
Ph.D., Duke University.
Charles H. Brett, Professor of Entomology.
Ph.D., Kansas State College.
Richard Bright, Professor of Chemical Engineering.
M.S., State University of Iowa.
Charles A. Brim, Associate Professor of Crop Science.
Ph.D., University of Nebraska.
Henry Seawell Brown, Associate Professor of Geological Engineering.
Ph.D., University of Illinois.
Marvin L. Brown, Jr., Professor of History and Political Science.
Ph.D., University of Pennsylvania.
Wesley Gordon Bruce, Visiting Professor of Entomology.
M.S., Kansas State College.
Roberts Cozart Bullock, Professor of Mathematics.
Ph.D., University of Chicago.
Carl Lee Bumgardner, Associate Professor of Chemistry.
Ph.D., Massachusetts Institute of Technology.
Fred Virgil Cahill, Jr., Professor of History and Political Science and Dean of the School of General Studies.
Ph.D., Yale University.
John Tyler Caldwell, Professor of Political Science and Chancellor.
Ph.D., Princeton University.
Kenneth Stoddard Campbell, Professor of Textile Chemistry.
B.S., Bates College.
Malcolm Eugene Campbell, Professor of Textiles and Dean of the School of Textiles.
B.S., Clemson College.
William V. Campbell, Associate Professor of Entomology.
Ph.D., North Carolina State.
Thomas Franklin Cannon, Associate Professor of Horticultural Science.
Ph.D., Ohio State University.
George L. Capel, Professor of Agricultural Economics.
Ph.D., University of Florida.

Robert Gordon Carson, Jr., Professor of Industrial Engineering and Director of Instruction for School of Engineering.
Ph.D., University of Michigan.
Roy Merwin Carter, Professor of Wood Technology.
M.S., Michigan State College.
Edward Vitangelo Caruolo, Assistant Professor of Animal Science.
Ph.D., University of Minnesota.
David Marshall Cates, Professor of Textile Chemistry.
Ph.D., Princeton University.
John Wesley Cell, Professor of Mathematics and Head of Department.
Ph.D., University of Illinois.
Douglas Scales Chamblee, Professor of Crop Science.
Ph.D. Iowa State College.
Norman M. Chansky, Associate Professor of Agricultural Education and Psychology.
Ph.D., Columbia University.
John Montgomery Clarkson, Professor of Mathematics.
Ph.D., Cornell University.
Albert J. Clawson, Associate Professor of Animal Science.
Ph.D., Cornell University.
Carlyle Newton Clayton, Professor of Plant Pathology.
Ph.D., University of Wisconsin.
Grover Cleveland Cobb, Jr., Assistant Professor of Physics.
Ph.D., University of Virginia.
Fred Derward Cochran, Professor of Horticulture and Head of Department.
Ph.D., University of California.
Columbus Clark Cockerham, Professor of Experimental Statistics.
Ph.D., Iowa State College.
Eloise Snowden Cofer, Assistant Director, Agricultural Extension (Home Economics).
Ph.D., University of Chicago.
Norval White Conner, Professor of Mechanical Engineering and Director of Department of Engineering Research.
M.S., Iowa State College.
William Stokes Connor, Adjunct Professor of Experimental Statistics.
Ph.D., University of North Carolina.
Freeman Waldo Cook, Associate Professor of Poultry Science.
M.S., North Carolina State.
John Oliver Cook, Associate Professor of Psychology.
Ph.D., New York University.
Maurice Gayle Cook, Assistant Professor of Soil Science.
Ph.D., Virginia Polytechnic Institute.
Arthur W. Cooper, Associate Professor of Botany and Bacteriology.
Ph.D., University of Michigan.
William Earl Cooper, Associate Professor of Plant Pathology.
Ph.D., Louisiana State University.
Alonzo Freeman Coots, Associate Professor of Chemistry.
Ph.D., Vanderbilt University.
Will Allen Cope, Associate Professor of Crop Science.
Ph.D., North Carolina State.
Harold Maxwell Corter, Professor of Psychology and Director of Psychological Clinic.
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Arthur James Coutu, Professor of Agricultural Economics.
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Frank Rankin Craig, Professor of Poultry Science.
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Paul Day Cribbins, Associate Professor of Civil Engineering.
Ph.D., Purdue University.
George A. Cummings, Assistant Professor of Soil Science.
Ph.D., Purdue University.
Edmund Pendleton Dandridge, Associate Professor of English.
Ph.D., University of Virginia.
Walter Carl Dauterman, Assistant Professor of Entomology.
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Donald Gould Davenport, Assistant Professor of Animal Science.
M.S., Cornell University.
Charles Bingham Davey, Associate Professor of Soil Science.
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Henry Mauzee Davis, Adjunct Professor of Mineral Industries.
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William Robert Davis, Associate Professor of Physics.
Doktor der Naturwiss, University of Hanover, Germany.
James William Dickens, Assistant Professor of Agricultural Engineering.
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Ph.D., University of Missouri.
George Osmore Doak, Professor of Chemistry.
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Wesley Osborne Doggett, Professor of Physics.
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William Emmert Donaldson, Assistant Professor of Poultry Science.
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Jesse Seymour Doolittle, Professor of Mechanical Engineering and Graduate Administrator.
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Louis A. Dow, Associate Professor of Economics.
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John W. Duffield, Professor of Forestry.
Ph.D., University of California.
Arthur Raymond Eckels, Professor of Electrical Engineering.
D. Eng., Yale University.
Preston William Edsall, Professor of History and Political Science and Head of Department.
Ph.D., Princeton University.

John Auert Edwards, Assistant Professor of Engineering Mechanics.
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William Frederick Edwards, Associate Professor of Social Studies.
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Don Edwin Ellis, Professor of Plant Pathology and Head of Department.
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Eric Louis Ellwood, Professor of Wood Science and Technology and Head of Department.
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Munir R. El-Saden, Associate Professor of Mechanical Engineering.
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Donald Allen Emery, Associate Professor of Crop Science.
Ph.D., University of Wisconsin.
John Lincoln Etchells, Professor of Food Science and Botany and Bacteriology.
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Ralph Eigil Fadum, Professor of Civil Engineering and Dean of the School of Engineering.
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Ph.D., Johns Hopkins University.
Daniel Fromm, Associate Professor of Food Science.
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Alan Stuart Galbraith, Adjunct Professor of Mathematics.
Ph.D., Harvard University.
Gene John Galletta, Assistant Professor of Horticultural Science.
Ph.D., University of California.
Gerald Garb, Associate Professor of Economics.
Ph.D., University of California.
Bertram Howard Garcia, Jr., Associate Professor of Mechanical Engineering.
M.S., Pennsylvania State University.
Monroe Evans Gardner, Professor of Horticultural Science.
B.S., Virginia Polytechnic Institute.
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Forrest William Getzen, Associate Professor of Chemistry.
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William Best Gilbert, Assistant Professor of Crop Science.
Ph.D., North Carolina State.
Edward Walker Glazener, Professor of Poultry Science and Director of Instruction for the School of Agriculture and Life Sciences.
Ph.D., University of Maryland.
William Alexander Glenn, Adjunct Associate Professor of Industrial Engineering and Experimental Statistics.
Ph.D., Virginia Polytechnic Institute.
Lemuel Goode, Associate Professor of Animal Science.
M.S., University of West Virginia.
Guy Vernon Gooding, Assistant Adjunct Professor of Plant Pathology.
Ph.D., University of California.
Bruce Edward Goodwin, Assistant Professor of Mathematics.
Ph.D., Rensselaer Polytechnic Institute.
Gilbert Gottlieb, Adjunct Assistant Professor of Psychology.
Ph.D., Duke University.
Arnold H. E. Grandage, Professor of Experimental Statistics.
Ph.D., North Carolina State.
Ralph Weller Greenlaw, Associate Professor of History and Political Science.
Ph.D., Princeton University.
Walton Carlyle Gregory, William Neal Reynolds Distinguished Professor of Crop Science.
Ph.D., University of Virginia.
John Edward Griffith, Associate Professor of Engineering Mechanics and Graduate Administrator.
Ph.D., Pennsylvania State University.
Daniel Swartwood Grosch, Professor of Genetics.
Ph.D., University of Pennsylvania.
Harry Douglas Gross, Associate Professor of Crop Science.
Ph.D., Iowa State College.
Elliott Brown Grover, Abel C. Lineberger Professor of Textiles and Head of Department of Textile Technology.
B.S., Massachusetts Institute of Technology.
George Albert Gullette, Professor of Social Studies and Head of Department.
Ph.D., University of Michigan.
Edward DeWitt Gurley, Assistant Professor of Engineering Mechanics.
Ph.D., University of Illinois.
Frank Edwin Guthrie, Professor of Entomology and Assistant Dean of the Graduate School for Research.
Ph.D., University of Illinois.
Frank Arlo Haasis, Professor of Plant Pathology.
Ph.D., Cornell University.
William Cullen Hackler, Associate Professor of Mineral Industries.
Ph.D., North Carolina State.
Robert John Hader, Professor of Experimental Statistics.
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William Jackson Hall, Associate Professor of Experimental Statistics.
Ph.D., University of North Carolina.

Dame Scott Hamby, Burlington Industries Professor of Textiles.
B.S., Alabama Polytechnic Institute.
Charles Horace Hamilton, William Neal Reynolds Distinguished Professor of Rural Sociology.
Ph.D., University of North Carolina.
John Valentine Hamme, Associate Professor of Mineral Industries.
Ph.D., North Carolina State.
Durwin M. Hanson, Professor of Industrial Education and Head of Department.
Ph.D., Iowa State University.
Karl P. Hanson, Professor of Mechanical Engineering.
M.S., University of Michigan.
Warren Durward Hanson, Professor of Genetics.
Ph.D., Purdue University.
James W. Hardin, Associate Professor of Botany and Bacteriology.
Ph.D., University of Michigan.
Reinard Harkema, Professor of Zoology.
Ph.D., Duke University.
Cleon Wallace Harrell, Associate Professor of Economics.
M.A., University of Virginia.
Walter Joel Harrington, Professor of Mathematics.
Ph.D., Cornell University.
Clarence Arthur Hart, Associate Professor of Forestry.
Ph.D., North Carolina State.
Lodwick Charles Hartley, Professor of English and Head of Department.
Ph.D., Princeton University.
Paul Henry Harvey, William Neal Reynolds Distinguished Professor of Crop Science and Head of Department.
Ph.D., Iowa State College.
Hassan Ahmad Hassan, Professor of Mechanical Engineering.
Ph.D., University of Illinois.
Francis Jefferson Hassler, Professor of Agricultural Engineering and Head of Department.
Ph.D., Michigan State College.
William Walter Hassler, Associate Professor of Zoology.
Ph.D., University of Tennessee.
Arthur Courtney Hayes, Associate Professor of Textile Chemistry.
M.S., North Carolina State.
Don W. Hayne, Visiting Professor of Experimental Statistics.
Ph.D., University of Michigan.
Frank Lloyd Haynes, Jr., Professor of Horticultural Science.
Ph.D., Cornell University.
Teddy Theodore Hebert, Professor of Plant Pathology.
Ph.D., North Carolina State.
Walter A. Hendricks, Adjunct Professor of Experimental Statistics.
M.A., George Washington University.
William Ray Henry, Associate Professor of Agricultural Economics.
Ph.D., North Carolina State.
Laurence Jay Herbst, Assistant Professor of Experimental Statistics.
Ph.D., Harvard University.
Robert Taylor Herbst, Adjunct Associate Professor of Mathematics.
Ph.D., Duke University.
Francis Eugene Hester, Associate Professor of Zoology.
Ph.D., Alabama Polytechnic Institute.

Charles Horace Hill, Professor of Poultry Science.
Ph.D., Cornell University.
Thomas I. Hines, Professor of Recreation and Park Administration and Head of Department.
M. A., University of North Carolina.
George Burnham Hoadley, Professor of Electrical Engineering and Head of Department.
D.Sc., Massachusetts Institute of Technology.
Charles S. Hodges, Jr., Associate Professor of Plant Pathology.
Ph.D., University of Georgia.
Ernest Hodgson, Associate Professor of Entomology.
Ph.D., Oregon State University.
Abraham Holtzman, Professor of History and Political Science.
Ph.D., Harvard University.
William Calvin Hood, Assistant Professor of Mineral Industries.
Ph.D., Montana State University.
Dale Max Hoover, Associate Professor of Agricultural Economics.
Ph.D., University of Chicago.
Maurice W. Hoover, Professor of Food Science.
Ph.D., University of Florida.
John William Horn, Associate Professor of Civil Engineering.
M.S.C.E., Massachusetts Institute of Technology.
Daniel Goodman Horvitz, Adjunct Professor of Experimental Statistics.
Ph.D., Iowa State College.
Ivan Hostetler, Professor of Industrial Arts Education and Head of Department.
Ed.D., University of Missouri.
Barney Kuo-Yen Huang, Assistant Professor of Agricultural Engineering.
Ph.D., Purdue University.
George Hyatt, Jr., Professor of Animal Science and Director of Agricultural Extension Service.
Ph.D., University of Wisconsin.
Loren Albert Ihnen, Assistant Professor of Agricultural Economics.
Ph.D., Iowa State University.
Makoto Itoh, Visiting Professor of Electrical Engineering and Mathematics.
Ph.D., Hiroshima University.
William A. Jackson, Associate Professor of Soil Science.
Ph.D., North Carolina State.
Gerald Blaine James, Adjunct Associate Professor of Agricultural Education.
Ed.D., University of Illinois.
Herman Brooks James, Professor of Agricultural Economics and Dean of the School of Agriculture and Life Sciences.
Ph.D., Duke University.
Benjamin Anderson Jayne, Professor of Wood Science and Technology.
B.S., University of Idaho.
John Mitchell Jenkins, Jr., Professor of Horticultural Science.
Ph.D., University of Minnesota.
Harley Young Jennings, Professor of Textile Research.
Ph.D., University of Michigan.
Elmer Hubert Johnson, Professor of Sociology and Anthropology.
Ph.D., University of Wisconsin.
Joseph Clyde Johnson, Associate Professor of Psychology.
Ed.D., Peabody College.
Paul R. Johnson, Associate Professor of Agricultural Economics.
Ph.D., University of Chicago.

William Hugh Johnson, Assistant Professor of Agricultural Engineering.
Ph.D., North Carolina State.
Edgar Walton Jones, Assistant Professor of Agricultural Economics.
Ph.D., North Carolina State.
Guy Langston Jones, Professor of Crop Science.
Ph.D., University of Minnesota.
Ivan Dunlavy Jones, Professor of Food Science.
Ph.D., University of Minnesota.
Louis Allman Jones, Associate Professor of Chemistry.
Ph.D., Texas Agricultural and Mechanical College.
Kenneth Allan Jordan, Assistant Professor of Agricultural Engineering.
Ph.D., Purdue University.
Charles Howard Kahn, Associate Professor of Architecture.
M.S., Massachusetts Institute of Technology.
Joseph S. Kahn, Assistant Professor of Botany and Bacteriology.
Ph.D., University of Illinois.
Eugene J. Kamprath, Professor of Soil Science.
Ph.D., North Carolina State.
Morley Richard Kare, Professor of Poultry Science and Zoology.
Ph.D., Cornell University.
Abdel-Aziz Ismail Kashef, Visiting Lecturer of Civil Engineering.
Ph.D., Purdue University.
Gerald Howard Katzin, Assistant Professor of Physics.
Ph.D., North Carolina State.
Kenneth Raymond Keller, Professor of Crop Science and Assistant Director in Charge of Tobacco Research.
Ph.D., Iowa State College.
Harry Charles Kelly, Professor of Physics and Dean of Faculty.
Ph.D., Massachusetts Institute of Technology.
Joseph Wheeler Kelly, Professor of Poultry Science.
Ph.D., Iowa State College.
Arthur Kelman, William Neal Reynolds Distinguished Professor of Plant Pathology and Professor of Forestry.
Ph.D., North Carolina State.
Henderson Grady Kincheloe, Professor of English.
Ph.D., Duke University.
Richard Adams King, M. G. Mann Professor of Agricultural Economics.
Ph.D., Harvard University.
James Bryant Kirkland, Professor of Agricultural Education and Dean of the School of Education.
Ph.D., Ohio State University.
David M. Kline, Associate Professor of Plant Pathology.
Ph.D., University of Wisconsin.
Glenn Charles Klingman, Professor of Crop Science.
Ph.D., Rutgers University.
Richard Bennett Knight, Professor of Mechanical Engineering.
M.S., University of Illinois.
Toyoki Koga, Professor of Mechanical Engineering.
Ph.D., Tokyo University.
Ken-ichi Kojima, Associate Professor of Genetics.
Ph.D., North Carolina State.
Benjamin Granade Koonce, Jr., Associate Professor of English.
Ph.D., Princeton University.

John Clement Koop, Visiting Associate Professor of Experimental Statistics.
Ph.D., North Carolina State.
William Wurth Kriegel, Professor in Charge of Ceramic Engineering.
Dr. Ing., Technische Hochschule, Hanover, Germany.
Leaton John Kushman, Associate Professor of Horticultural Science.
M.S., George Washington University.
Robert Walter Lade, Assistant Professor of Electrical Engineering.
Ph.D., Carnegie Institute of Technology.
John Ralph Lambert, Professor of Social Studies.
Ph.D., Princeton University.
Joe Oscar Lammi, Professor of Forestry.
Ph.D., University of California.
*Harold Augustus Lamonds, Professor of Nuclear Engineering.
Ph.D., North Carolina State.
Forrest Wesley Lancaster, Professor of Physics.
Ph.D., Duke University.
Roy Axel Larson, Assistant Professor of Horticultural Science.
Ph.D., Cornell University.
James Giacomo Lecce, Professor of Animal Science.
Ph.D., University of Pennsylvania.
James Murray Leatherwood, Assistant Professor of Animal Science.
Ph.D., North Carolina State.
Thomas Benson Ledbetter, Assistant Professor of Mechanical Engineering.
M.S., North Carolina State.
Joshua Alexander Lee, Assistant Professor of Crop Science.
Ph.D., University of California.
Richard Shao-Lin Lee, Associate Professor of Mechanical Engineering.
Ph.D., Harvard University.
James Edward Legates, William Neal Reynolds Distinguished Professor of Animal Science and Head of Animal Breeding Section.
Ph.D., Iowa State College.
Samuel George Lehman, Professor Emeritus of Plant Pathology.
Ph.D., Washington University.
Carlton James Leith, Associate Professor of Mineral Industries.
Ph.D., University of California.
Jack Levine, Professor of Mathematics.
Ph.D., Princeton University.
William Mason Lewis, Associate Professor of Crop Science.
Ph.D., University of Minnesota.
David Allen Link, Assistant Professor of Agricultural Engineering.
Ph.D., Iowa State University.
Robert W. Llewellyn, Professor of Industrial Engineering.
M.S., Purdue University.
Richard Henry Loeppert, Professor of Chemistry.
Ph.D., University of Minnesota.
George Gilbert Long, Assistant Professor of Chemistry.
Ph.D., University of Florida.
Roy Lee Lovvorn, Professor of Crop Science and Director of Research in the School of Agriculture.
Ph.D., University of Wisconsin.
Robert E. Lubow, Assistant Professor of Psychology, Poultry Science, and Zoology.
Ph.D., Cornell University.

* On leave until July, 1964

George Blanchard Lucas, Professor of Plant Pathology.
Ph.D., Louisiana State University.
Henry Laurence Lucas, Jr., William Neal Reynolds Distinguished Professor of Experimental Statistics.
Ph.D., Cornell University.
James Fulton Lutz, Professor of Soil Science.
Ph.D., University of Missouri.
Joseph Thomas Lynn, Associate Professor of Physics and Graduate Administrator.
M.S., Ohio State University.
*Glenn C. McCann, Associate Professor of Rural Sociology.
Ph.D., Washington State College.
Charles B. McCants, Professor of Soil Science.
Ph.D., Iowa State College.
Robert E. McCollum, Assistant Professor of Soil Science.
Ph.D., University of Illinois.
Clarence Leslie McCombs, Professor of Horticultural Science.
Ph.D., Ohio State University.
Ralph Joseph McCracken, Professor of Soil Science and Head of Department.
Ph.D., Iowa State College.
Charles Russell McCullough, Professor of Civil Engineering.
M.S., Purdue University.
Donald McDonald, Assistant Professor of Civil Engineering.
M.S., University of Illinois.
Patrick Hill McDonald, Professor of Engineering Mechanics and Head of Department.
Ph.D., Northwestern University.
John Joseph McNeill, Assistant Professor of Animal Science.
Ph.D., University of Maryland.
Francis Edward McVay, Professor of Experimental Statistics.
Ph.D., University of North Carolina.
James Gray Maddox, Professor of Agricultural Economics.
Ph.D., Harvard University.
Alexander Russell Main, Associate Professor of Entomology.
Ph.D., Cambridge University.
T. Ewald Maki, Carl Alwin Schenck Professor of Forest Management.
Ph.D., University of Minnesota.
Carroll Lamb Mann, Jr., Professor of Civil Engineering.
C.E., Princeton University.
Thurston Jefferson Mann, Professor of Genetics and Head of Department.
Ph.D., Cornell University.
Edward George Manning, Associate Professor of Electrical Engineering.
M.S., North Carolina State.
Edward Raymond Manring, Professor of Physics.
Ph.D., Ohio State.
Culpepper Paul Marsh, Associate Professor of Rural Sociology.
M.S., North Carolina State.
David Boyd Marsland, Associate Professor of Chemical Engineering.
Ph.D., Cornell University.
David Hamilton Martin, Assistant Professor of Physics.
M.S., University of Wisconsin.
Bernard Stephen Martof, Professor of Zoology and Head of Department.
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* On leave until July, 1965

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Ph.D., North Carolina State.
Gennard Matrone, Professor of Animal Science.
Ph.D., North Carolina State.
Dale Frederick Matzinger, Associate Professor of Genetics.
Ph.D., Iowa State College.
Jackson R. Mauney, Associate Professor of Crop Science.
Ph.D., University of Wisconsin.
Selz Cabot Mayo, Professor of Rural Sociology and Head of Department; Head of Department of Sociology and Anthropology.
Ph.D., University of North Carolina.
Jefferson Sullivan Meares, Professor of Physics.
M.S., North Carolina State.
Arthur Clayton Menius, Jr., Professor of Physics and Dean of the School of Physical Sciences and Applied Mathematics.
Ph.D., University of North Carolina.
Lawrence Eugene Mettler, Associate Professor of Genetics.
Ph.D., University of Texas.
Gordon Kennedy Middleton, Professor Emeritus of Crop Science.
Ph.D., Cornell University.
Robert Donald Milholland, Assistant Professor of Plant Pathology.
Ph.D., University of Minnesota.
Conrad Henry Miller, Associate Professor of Horticultural Science.
Ph.D., Michigan State University.
Darrell Alvin Miller, Assistant Professor of Genetics and Plant Breeding.
Ph.D., Purdue University.
Grover Cleveland Miller, Associate Professor of Zoology.
Ph.D., Louisiana State University.
Howard G. Miller, Professor of Psychology and Head of Department.
Ph.D., Pennsylvania State University.
Philip Arthur Miller, Professor of Crop Science.
Ph.D., Iowa State.
Raymond Jarvis Miller, Associate Professor of Soil Science.
Ph.D., Purdue University.
Walter Joseph Mistric, Associate Professor of Entomology.
Ph.D., A & M College of Texas.
Adolphus Mitchell, Professor of Engineering Mechanics.
M.S., University of North Carolina.
Theodore Bertis Mitchell, Professor Emeritus of Entomology.
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Robert James Monroe, Professor of Experimental Statistics.
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Marvin Kent Moss, Assistant Professor of Physics.
Ph.D., North Carolina State.
Carey Gardner Mumford, Professor of Mathematics and Assistant to Dean of the School of Physical Sciences and Applied Mathematics.
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INDEX

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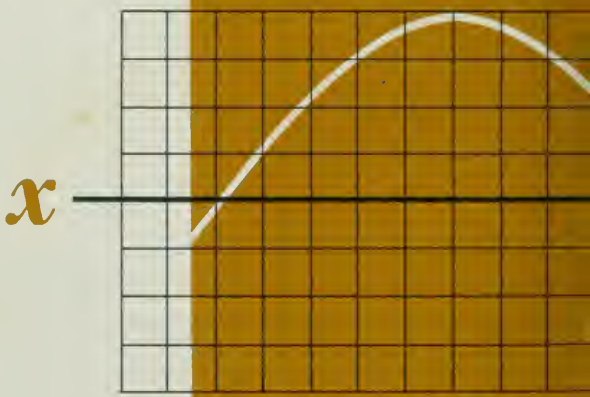
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